

**DECLARATION OF GLENN W. JOHNSON, Ph.D.**

1. My name is Glenn W. Johnson. I am over the age of 21, and I am competent to testify to the facts stated herein. This declaration is based on my personal knowledge and training.
2. A complete listing of my educational background, various positions held by me and the publications, book chapters, abstracts and presentations authored by me is contained in my Curriculum Vita, a true and correct copy of which was attached to my November 2008 expert.<sup>1</sup> By way of summary, my 1997 Ph.D. dissertation at the University of South Carolina concerned application of PCA-based multivariate statistical methods to environmental geochemistry. I have published 14 peer-reviewed publications, and 6 book chapters relating directly to PCA and similar multivariate statistical tools. In my 20+ years as an environmental professional, I have applied these methods to a broad range of chemicals and other environmental parameters (PCBs, inorganics/metals, dioxins, volatile organic compounds, polycyclic aromatic hydrocarbons, crude oil, biological census counts) and I have worked with data sets that include the following media: rock, soil, sediment, surface water, groundwater, air, and suspended particulate matter in water.
3. I have been retained as an expert witness on behalf of the Defendants in the case of State of Oklahoma, et al. v. Tyson Foods, Inc., et al., et al., pending in the United States District Court for the Northern District of Oklahoma, and bearing on Civil Action No. No. 05-CV-329-GKF-PJC.
4. I have reviewed material provided by the state of Oklahoma, and consultants to the state, giving opinions as to the merits of their case. I submitted the expert report referenced above on November 21, 2008 (Johnson, 2008). This was a rebuttal report in response to the expert report of plaintiff's expert Dr. Roger Olsen.<sup>2</sup> The focus of my rebuttal was the degree to which a series of principal components analysis (PCA) runs conducted by Olsen, support his conclusions with regard to sources of phosphorus, bacteria and other constituents in the Illinois River Watershed (IRW). I subsequently submitted myself for deposition on February 24-25, 2009 in the above referenced matter, and in the same styled cause.

---

<sup>1</sup> Johnson, G.W. (2008). Rebuttal Report Principal Components Analysis of Geochemical Data from the Illinois River Watershed, Northwest Arkansas and Eastern Oklahoma. November 21, 2008.

<sup>2</sup> Olsen, R.L. (2008). Expert Report of Roger L. Olsen. Prepared for A. Drew Edmondson, Attorney General of the State of Oklahoma. May 14, 2008. 170 pp. 72 tables. 153 figures. (Ex. 2A).

5. In my November 21 report, I identified and discussed numerous problems in the principal components analysis (PCA) of Dr. Olsen. On May 18, 2009 plaintiffs filed a motion<sup>3</sup> challenging one aspect of my testimony, specifically my opinion that one of the primary controls on Olsen's surface water PCA was how chemicals included in that analysis redistribute in the environment according to their affinity for the dissolved phase versus association with suspended particulate matter. Plaintiffs' motion included 4 exhibits: (a) four pages excerpted from my November 21, 2008 Expert Report; (b) excerpts from my deposition testimony of February 24-25, 2009; (c) the May 18, 2009 declaration by Dr. Jim Loftis of Colorado State University; and (d) a May 15, 2009 declaration of Dr. Roger Olsen of CDM. In this declaration, I respond to the allegations presented in plaintiffs' motion and associated exhibits.
6. **Allegation 1: Johnson Opines that Water Quality Problems are Due to Natural Processes:** In their motion, plaintiffs incorrectly represent my opinion by claiming that I "*mistakenly conclude that the IRW water quality problems are due to natural processes*"<sup>4</sup> This suggests that I have opined that elevated concentrations of phosphorus in the IRW are a naturally occurring phenomenon. That is not my opinion. I have opined that regardless of source (not in absence of source) the major control on the observed variability in Olsen's surface water PCA data set is partitioning between the particulate phase and the dissolved phase. This is a natural process that renders the PCA ineffective in distinguishing between the numerous potential sources in the IRW. My opinion on this matter is accurately expressed in my own words, within my report:

*"By assuming from the outset that source signatures control this data set, Olsen completely missed the two primary controls on the surface water and groundwater data sets: (1) total concentration; and (2) how chemicals redistribute in the environment according to their affinity for the dissolved phase versus association with suspended particulate matter. Olsen's PCA cannot be used to infer any source of contamination to the IRW, let alone poultry."*<sup>5</sup>

*"to the extent that total phosphorus is explained by his [Olsen's] analysis, it is because variability of total phosphorus is a function of its association with iron, aluminum and suspended particulate matter".*<sup>6</sup>

<sup>3</sup> State of Oklahoma's Motion in Limine to Preclude Expert Testimony of Defendants' Witness Dr. Glenn Johnson, Ph.D., Dkt. No. 2083 (May 18, 2009)

<sup>4</sup> Motion to Exclude Johnson Testimony. p. 3, ¶ 1, lines 4-5.

<sup>5</sup> Johnson (2008). p. 5. Final Bullet.

<sup>6</sup> Johnson (2008). p. 70. ¶ 3. Lines 12-14.

7. **Allegation 2: Lack of Factual Background: Source Evaluation.** In their motion to exclude my testimony, plaintiffs claim that I did no analysis of potential sources.<sup>7</sup> I am baffled by this allegation. Their support for this claim is deposition testimony where I said that I could not opine on contribution of specific sources. That was not because I did no analysis of potential sources. Rather, it was because I did an exhaustive analysis in the context of Dr. Olsen's PCA, and showed beyond any doubt that his theory of a source driven system, dominated by poultry waste was untenable.

As indicated in both my report and deposition testimony, I conducted a tour of the IRW in July 2008,<sup>8</sup> which included both aerial and driving tours of the watershed. With respect to source evaluation and that tour, I personally observed waste-water treatment plants, nurseries, urban population centers, and agricultural lands (poultry and otherwise) all of which can contribute phosphorus to the watershed.

In addition, analysis of potential sources in context of Dr. Olsen's PCA was one of, if not the most important aspect of my report. I addressed cattle sources in my report.<sup>9</sup> Four water samples (2 edge-of-field, 2 groundwater/spring samples) were collected by plaintiffs' consultants under the presumption that they represented impact from cattle. All four of those samples yielded PCA results that by Olsen's own PCA-based criterion classified them as impacted by poultry-waste.

I addressed waste water treatment plant sources in my report<sup>10</sup>. Four water samples were collected by plaintiffs' consultants under the presumption that they represented impact from waste water treatment plants. Again all four yielded PCA results that (by Olsen's criterion) classified them as impacted by poultry-waste.

I addressed sources from urban areas (i.e. areas of high human population) in my report.<sup>11</sup> I presented a series of maps showing numerous examples of samples that (1) were collected in or immediately downstream of IRW urban areas (e.g. Tahlequah, Fayetteville, Lincoln, Siloam

<sup>7</sup> See Plaintiffs' Motion to Exclude Johnson Testimony; p. 2 (final paragraph; which continues on to p. 3).

<sup>8</sup> See Johnson (2008: p. 4 ¶ 3). Johnson Deposition: 89: 4 to 90:11 (Ex. 2C).

<sup>9</sup> See Johnson (2008: pp. 26-29; p. 40-50).

<sup>10</sup> See Johnson (2008: pp. 37-39).

<sup>11</sup> See Johnson (2008: pp. 34-37; pp. 51-56).

Springs, Westville, Rogers);<sup>12</sup> and (2) were located in areas that Olsen had identified as having zero poultry-house density.<sup>13</sup> But again, these samples yielded PCA results that (by Olsen's criterion) classified them as impacted by poultry-waste. Of the urban areas listed above, I focused particular attention Tahlequah, Oklahoma, because it not only represented a contradiction of his source identification criterion, it exposed a fatal flaw in the logic used to establish that criterion in the first place.<sup>14</sup>

I also noted in my report that other potential sources in the watershed were possible, but could not be evaluated in the context of Olsen's PCA because plaintiffs' consultants failed to collect samples to characterize them.<sup>15</sup> The final summary paragraph of my report is probably the most important take-home point made therein, and it is in fact a recap of my source evaluation. I conclude my report by pointing out that of the relatively small number of samples collected by Olsen and his colleagues with presumption or intent of characterizing sources other than poultry, every single one yielded PCA scores that fit Olsen's criterion for his *unique poultry waste signature*.<sup>16</sup> This was a crucial part of the *factual foundation* that necessitated an alternative geochemical interpretation.

8. **Allegation 3: Dr. Johnson is not qualified to opine on geochemical partitioning and phosphorus.** Plaintiffs argue that my experience is essentially limited to synthetic hazardous wastes such as PCBs, and that this is my first experience with geochemical issues salient to this case.<sup>17</sup> Therefore they assert that I have opined outside my area of expertise;<sup>18</sup> that I lack prerequisite knowledge of chemical kinetics necessary to opine on the controls phosphorus adsorption might exert on Olsen's PCA;<sup>19</sup> and that I am not aware of (or otherwise chose to ignore) phosphorus concentration in context of Oklahoma's total phosphorus water quality standard.<sup>20</sup>

<sup>12</sup> See Johnson (2008: p. 35 (Fig. 3-1); p. 51 (Fig. 3-12); p. 52 (Fig. 3-13); p. 53 (Fig. 3-14); p. 55 (Fig. 3-15); p. 56 (Fig. 3-16) p. 60 (Fig. 4-3).

<sup>13</sup> My focus on these samples in context of Olsen's poultry-house density data (Figure 2.5-1) was in specific response to Olsen stated opinion that poultry house density is "*a surrogate for poultry waste land applications*" and "*an excellent predictor of stream phosphorus concentrations in the watershed*" (Olsen Expert Report (Ex. 2A) p. 6-30: ¶14).

<sup>14</sup> Johnson (2008). Section 3.1; pp. 34-37.

<sup>15</sup> See Johnson (2008: p. 10)

<sup>16</sup> See Johnson (2008: p. 71).

<sup>17</sup> See Plaintiffs' Motion to Exclude Dr. Johnson (p.2 1<sup>st</sup> paragraph of Section II).

<sup>18</sup> See Plaintiffs' Motion to Exclude Dr. Johnson (p. 1: Introductory Statement).

<sup>19</sup> See Plaintiffs' Motion to Exclude Johnson Testimony. p. 3: Final paragraph; p. 7 Final paragraph.

<sup>20</sup> See Plaintiffs' Motion to Exclude Johnson Testimony. p. 3: Final paragraph. Last 3 lines of page.

As outlined in paragraph 7 above, it was the very failure of Olsen's source driven interpretation that led me to explore alternative interpretations of his PCA. The essence of Plaintiffs' motion to exclude my testimony is that I should not have done so because the subject matter is not within my base of knowledge. Plaintiffs either misunderstood or deliberately chose to ignore my professional qualifications in this area.

While I have focused much of my career on multivariate statistics (and in particular PCA), my degrees are in geology, and my experience is not limited to "*PCBs and other synthetic hazardous substance*."<sup>21</sup> My 1997 Ph.D. dissertation at the University of South Carolina<sup>22</sup> concerned the application of PCA-based multivariate statistical methods to environmental geochemical data. My dissertation included three case studies, only one of which addressed *synthetic hazardous substances* - and even that case-study is relevant to the subject of this motion, as it concerned adsorption of chemicals to suspended sediment in surface water. That case-study was a PCA-based source-apportionment study concerning PCBs, and the media studied was suspended sediment in surface water, to which the PCBs were adsorbed.

The other two case studies in my dissertation concerned application of PCA based methods to inorganics in ground water. These chemicals are not "*PCBs and synthetic hazardous substances*." Both case studies are directly relevant to the issues in dispute here, because in each, the predominant control on the observed variability was geochemical process, not source. One of these was conducted with the objective of identifying sources of metals contamination in groundwater, and focused on distinguishing between anthropogenic (source) and process related fingerprints. It is also noteworthy that one of the resolved chemical signatures in this study was identified as reflecting the amount of suspended sediment in water.

The third case study in my dissertation also involved inorganic chemicals in groundwater. Once again, chemical process was the primary controlling factor observed, and in regard to the PCA-based fingerprinting results, I concluded the following:

*"..hydrochemistry is largely a function of chemical evolution along groundwater flow paths rather than physical mixing of groundwater from different sources. The end-members are not sources of groundwater, but rather related to geochemical processes that alter the chemical composition of groundwater. As we will see in subsequent chapters, the correct identification and interpretation of*

<sup>21</sup> Plaintiffs' Motion to Exclude Johnson Testimony. Exhibit C: Declaration of Jim C. Loftis: p. 8 (¶ 18).

<sup>22</sup> Johnson, G.W. 1997. Application of Polytopic Vector Analysis to Environmental Geochemistry Investigations. Ph.D. Dissertation. Dept. of Geological Sciences, University of South Carolina, Columbia, South Carolina.

*process-related end-members will remain of primary concern, even when dealing with data sets that represent true source apportionment problems.*"<sup>23</sup>

The importance of identifying the effect natural processes have on a PCA, and the procedures for doing so, have been clear to me for more than 10 years. It is not a subject into which that I have wandered blindly and proceeded to spout uninformed opinion.

In a subsequent book-chapter that reviewed PCA-based methods in environmental forensics I cautioned the reader on the importance of considering and recognizing geochemical alteration processes, in specific context of how it can confound source identification using PCA-based receptor models:

*"Self-training receptor models are valuable tools in the analysis of large data sets from field areas where sources cannot be predicted ahead of time. However, environmental processes have the potential to confound receptor model results."*<sup>24</sup>

*"Given a situation of multiple sources, and patterns modified by one or more alteration processes, source apportionment is more difficult."*<sup>25</sup>

I have turned the attention of my more recent research to contaminants such as PCBs, not because I lack knowledge of inorganic geochemistry, or geochemical processes that control the distribution of such chemicals in the natural environment. Rather, it is based on that experience that I know that with inorganic chemicals, natural processes, fate/transport mechanisms can confound one's ability to identify sources in ambient data, especially in situations like Olsen's IRW data set which includes analytes with drastically different geochemical properties. The focus of my recent work on recalcitrant/hydrophobic chemicals (such as PCBs) is because such source signatures are better conserved in the environment

With this in mind, consider the assertion of Dr. Jim Loftis: that I am unqualified to comment on phosphorus because chemicals such as PCBs *"move and distribute in the environment much differently from phosphorus."*<sup>26</sup> Loftis fails to recognize one very important way that PCB fate and transport is directly relevant to the issue in dispute in plaintiffs' motion: partitioning between the particulate and dissolved phase. PCBs are hydrophobic, meaning that in aqueous systems, they do not tend to be found in high concentration in solution. Rather, they are found in highest

---

<sup>23</sup> Johnson Ph.D. Dissertation, 2007. Chapter 4. P. 79.

<sup>24</sup> Johnson, et al., (2007). Principal components analysis and receptor models in environmental forensics. In: An Introduction to Environmental Forensics. Murphy & Morrison, eds. Section 7.4. p. 251.

<sup>25</sup> Ibid. p. 252. 2<sup>nd</sup> ¶

<sup>26</sup> Plaintiffs' Motion to Exclude Johnson Testimony. Exhibit C: Declaration of Jim C. Loftis: p. 8 (¶ 18).

concentration in the sediment/particulate fraction.<sup>27</sup> To the degree that PCBs are found in surface water, they will be in higher concentrations adsorbed to suspended particulate matter rather than in solution.<sup>28</sup>

The important difference between PCBs and the analytes in Olsen's PCA is that all PCBs exhibit this similar geochemical affinity for sediment, so source-patterns (i.e. "fingerprints") are better conserved. In Olsen's PCA, some analytes are encountered almost entirely in solution (e.g. sodium); while others are associated predominantly with particulates/suspended sediment (e.g. iron and aluminum). The dramatic difference in the geochemical affinity of these analytes is not in dispute.<sup>29</sup> What is in dispute (and the main focus of plaintiff's motion) is whether such processes exert a strong control on total phosphorus in Olsen's PCA. Olsen claims that the variability in his PCA data set is due to the unique chemical signatures of sources, with poultry waste by far the dominant signature.<sup>30</sup> In contrast, I assert that the variability of total phosphorus in Olsen's PCA (regardless of source) is primarily a function of partitioning between the particulate and dissolved phase. The salient issues of this opinion are well within my background and training.

In their motion, plaintiffs point to deposition testimony where I could not quote partition coefficients that control phosphorus adsorption, the valence of an anionic complex, or the surface charge of suspended particles in water of a given pH.<sup>31</sup> Based on this, they assert that I do not have the requisite background to identify chemical partitioning as a process that exerts control in a PCA. Such data might be important if one were attempting to theoretically predict the amount of phosphorus that would adsorb to a colloid or mineral particle in water of a certain pH. Such prediction falls into the category of chemical kinetic modeling. PCA is not such a method. Rather, PCA is a multivariate statistical exploratory data analysis,<sup>32</sup> and to the extent that it is considered modeling, it falls into the empirical rather than predictive category. In my peer-

<sup>27</sup> This is why my publications that address sources of PCBs in surface water focus on the particulate-bound fraction. See: Jarman, et. al., (1997). Levels and patterns of polychlorinated biphenyls in water collected from the San Francisco Bay and Estuary, 1993-1995. *Fresenius J. Anal. Chem.* 359: 254-260.

Johnson, et al., (2000). Resolving polychlorinated biphenyl source fingerprints in suspended particulate matter of San Francisco Bay. *Environ. Sci. Technol.* 34: 552-559.

<sup>28</sup> See Johnson, et al., (2006). Chapter 10. Polychlorinated biphenyls. In: *Environmental Forensics: A Contaminant Specific Guide*. Morrison and Murphy, eds. Section 10.1.5. p. 194.

<sup>29</sup> Olsen Deposition. 9/10/08. 116: 23-25 (sodium) 77: 17:21 (iron & aluminum). Ex. 2B.

<sup>30</sup> Olsen Expert Report (2008). p. 1-2. 3<sup>rd</sup> full bullet. Ex. 2A.

<sup>31</sup> Plaintiffs' Motion to Exclude Johnson Testimony. p. 7. Final paragraph.

<sup>32</sup> See Johnson, et al. (2007). Principal components analysis and receptor models in environmental forensics. In: *An Introduction to Environmental Forensics*. Murphy & Morrison, eds.



reviewed PCA publications that have dealt with adsorption of chemicals to suspended particulate matter (cited above) we did not report or discuss our results in terms of kinetics (nor were we compelled to do so by reviewers/editors). Similarly, the basis of my opinion in this matter does not hinge on upon these issues. Rather, my opinion is a logical inference based on numerous undisputed/unchallenged observations. I made the unchallenged, empirical observation, using Olsen's own PCA score plots, that samples with high concentrations of chemicals known to have affinity for dissolved phase (e.g. sodium) preferentially plot in one area of Olsen's scores plot.<sup>33</sup> I made the unchallenged, empirical observation, that samples with high concentrations of chemicals known to be preferentially associated with suspended sediments (e.g. iron and aluminum) plot in a different area.<sup>34</sup> I made the unchallenged, empirical observation, that samples with high iron/aluminum concentrations also exhibit high concentrations of total suspended solids (TSS).<sup>35</sup> I pointed to the undisputed/unchallenged fact (and cited literature in support thereof) that sorption of phosphorus to suspended particulate matter is an important and common process in aqueous geochemical systems.<sup>36</sup> I cited peer-reviewed literature showing that total phosphorus exhibits a positive correlation with TSS in natural surface waters.<sup>37</sup> Taken in context of the established failure of Olsen's source-signature hypothesis (see paragraph 7 above) this led to the logical inference and my opinion that the process of partitioning between dissolved and particulate phases exerts a major control on Olsen's PCA, and confounds his (and anybody else's) ability to use it to infer sources of nutrients in the IRW. This was the basis of my opinion, and its foundation does not hinge on kinetic modeling or my ability to quote partition coefficients, a particle's surface charge or pH.

With regard to plaintiffs' allegation that I am unaware of phosphorus action levels under Oklahoma law<sup>38</sup> they cite the accompanying declaration of Dr. Jim Loftis. Loftis asserts that my analysis ignored concentration data, specifically with regard to phosphorus in comparison to the 0.037 mg/L Oklahoma water quality standard.<sup>39</sup> This assertion is demonstrably false. I did in fact conduct an analysis of total phosphorus concentrations in IRW surface water, and with specific

<sup>33</sup> Johnson Expert Report: p. 67 (Figure 4-10).

<sup>34</sup> Johnson Expert Report: p. 64 (Figure 4-7).

<sup>35</sup> Johnson Expert Report: p. 65 (Figure 4-8). This was particularly important because TSS was not included in Olsen's PCA. Therefore the TSS data independently confirm that iron and aluminum are a function of suspended sediment.

<sup>36</sup> Johnson Expert Report: p. 62.

<sup>37</sup> Johnson Expert Report: p. 62.

<sup>38</sup> See Plaintiffs' Motion to Exclude Johnson Testimony. Final complete sentence on p. 3.

<sup>39</sup> Plaintiffs' Motion to Exclude Johnson Testimony. Exhibit C: Declaration of Jim C. Loftis: p. 8 (¶ 19-20).



respect to the 0.037 criterion. I generated and reviewed total P concentration maps for stream water samples collected in the IRW (under both high-flow and low flow conditions) and in Lake Tenkiller. These maps were provided to plaintiffs in my production materials in December 2008<sup>40</sup> and they were discussed in my deposition.<sup>41</sup> On each of these maps (and with but a single exception) the concentration scale on the map legends are subdivided by unremarkable integers or fractions (e.g. .01 mg/L; .25 mg/L; 1 mg/L). The exception on each map is the 0.037 mg/L Oklahoma total phosphorus criterion. These maps were clearly designed to facilitate analysis of total P concentrations in context of this criterion. Plaintiffs point to the fact that I could not recall the number 0.037 on Day 2 of my deposition, and based on that, they assert that: (1) I conducted my analysis completely unaware of the Oklahoma total phosphorus criterion; (2) I choose not to consider concentrations of chemicals of concern in the IRW; (3) I am under the misguided impression that total phosphorus concentrations in the IRW represent naturally-occurring conditions. Clearly, these assertions are not true.

My report did not delve more deeply into issues of contaminant-of-concern (COC) concentrations in the IRW because they were addressed in much greater detail by defense experts Timothy Sullivan<sup>42</sup> and John Connolly.<sup>43</sup> And this brings me to the final point of this topic. To the extent that I opine on topics peripheral to my areas of recent research, I did not do so in a vacuum. In forming my opinion, I sought out and relied on the expertise and opinions of other experts. As I pointed out in deposition, during the process of preparation of my expert report, I collaborated with Drs. Sullivan and Connolly, and both participated in review and discussion of my expert report.<sup>44</sup>

Because the reports of Sullivan and Connolly were not written and submitted until 2 months after my report, I could not cite them. Given the existence of those reports now, I highlight several salient issues addressed by those gentlemen. With regard to phosphorus concentrations varying as a function of iron and aluminum, Connolly wrote:

*“These higher [phosphorus] concentrations may simply reflect the greater presence of iron and aluminum compounds (or calcium compounds) that naturally contain phosphorus or have the ability to bind phosphorus naturally present in the environment. In other words, there is no evidence that the total*

<sup>40</sup> Johnson Production Materials: GlennJohnson036462 (Total P in Base Flow Streams); GlennJohnson036484 (Total P High Flow Streams); and GlennJohnson036591 (Total P in Lake Tenkiller).

<sup>41</sup> Johnson Deposition. Vol. I. 52:25-53:16. Ex. 2C.

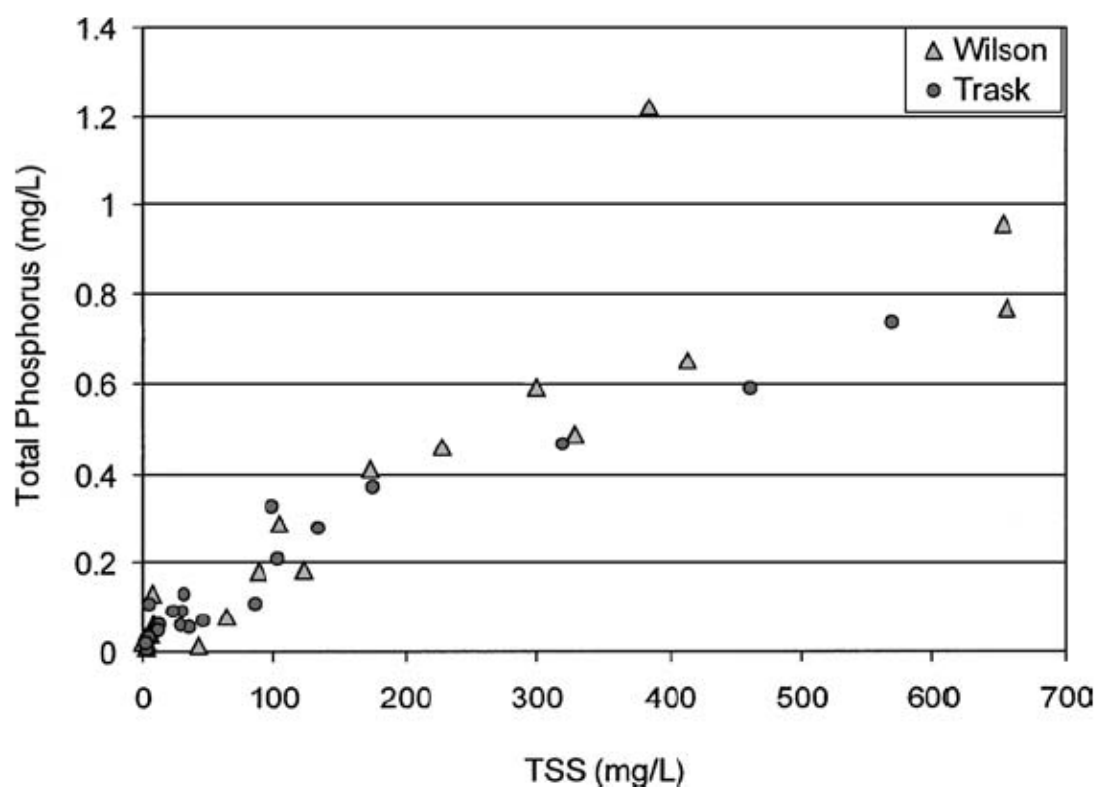
<sup>42</sup> Sullivan, T.J. (2009). Expert Report of Timothy J. Sullivan. January 29, 2009. Ex. 2D.

<sup>43</sup> Connolly, J. (2009) Expert Report: Illinois River Watershed Quality and Source Assessment. January 30, 2009. Ex. 2E.

<sup>44</sup> See Johnson Deposition. Vol. II. 500:13-501:6. Ex. 2C.

*phosphorus concentrations in stream sediments are higher than expected from soils running off of control fields. The total phosphorus concentrations differences among the stream sediment samples are the result of differences in the concentrations of Fe and Al in the material settling to the bottom.”<sup>45</sup>*

Similarly, I could not cite Sullivan’s January 29, 2009 report in a report I wrote two months before his was issued. But in preparation of my report, Dr. Sullivan alerted me to one of his peer-reviewed publications<sup>46</sup> that showed a strong empirically observed correlation between total suspended solids (TSS) and total phosphorus in surface water. The key figure from that paper is reproduced below. With the exception of single outlier, there is a clear and strong positive linear relationship between TSS and total phosphorus.



Sullivan’s paper was among the literature cited in my report in support of my opinion that variations of total phosphorus in the IRW are likely a function of TSS.<sup>47</sup> Subsequently, Sullivan’s January 2009 report addressed general issues of phosphorus concentration varying in surface water

<sup>45</sup> Connolly Expert Report (2009: p. 2-20 – last 7 lines). Ex. 2E.

<sup>46</sup> Sullivan, et al., (2005). Assessment of water quality in association with land use in the Tillamook Bay Watershed, Oregon, USA. Water, Air and Soil Pollution. 161: 3-23.

<sup>47</sup> Johnson (2008). p. 62.

as a function of suspended sediment and turbidity<sup>48</sup> as well as relevant literature and data with respect to phosphorus sources in the IRW and the 0.037 mg/L total-P water quality standard.<sup>49</sup>

In summary, through education and experience, I understand the salient issues of geochemistry and fate and transport. My opinion on geochemical partitioning was well-founded and based on numerous undisputed/unchallenged observations. I did not ignore total phosphorus concentration data. In forming my opinion with regard adsorption of total phosphorus, I did not do so in a vacuum. I relied on the literature, sought and received input from defendants' experts Sullivan and Connolly, who are eminently qualified in this area. However, given that evaluation of these geochemical concepts in context PCA falls squarely within my education, training and experience, they were fittingly addressed in my report.

**9. Allegation 4: Dr. Johnson's opinion hinges on the false assumption that most phosphorus in the IRW is particulate rather than dissolved.**

With regard to this allegation<sup>50</sup> plaintiffs cite the accompanying declaration of Dr. Olsen. Olsen states that for my opinion to be true, I must conclude that *"most of the phosphorus in the IRW is adsorbed ("bound") to particulates (suspended sediments) and that little phosphorus is in the dissolved form."* He points to literature that indicates that 80-90 percent of phosphorus runoff from fields is dissolved phase P, not particulate-bound P.<sup>51</sup> In his declaration,<sup>52</sup> Olsen then points to a line of questioning in my deposition<sup>53</sup> where I was shown tables of averages for dissolved and total phosphorus, for each of 8 sample types. The total phosphorus (P) and dissolved P averages addressed in that line of questioning are summarized in the table below. As is shown there, the average percent dissolved P in each of these sample types is greater than 50 percent.

<sup>48</sup> Sullivan (2009). p. 17 (Fourth full ¶); p. 26 (final ¶ continuing to p. 27); p. 34-¶4; Ex. 2D.

<sup>49</sup> Sullivan (2009). p.39 (1<sup>st</sup> three paragraphs). p. 48-49; p. 70-71. Ex. 2D.

<sup>50</sup> Plaintiffs' Motion to Exclude Johnson Testimony. p. 7; final paragraph: see item (3) and last full sentence of this paragraph.

<sup>51</sup> Plaintiffs' Motion to Exclude Johnson Testimony. Exhibit C: Declaration of Roger Olsen: p.12 (¶ 14).

<sup>52</sup> Plaintiffs' Motion to Exclude Johnson Testimony. Exhibit C: Declaration of Roger Olsen: pp. 15-29 (¶ 16-22).

<sup>53</sup> Johnson Deposition. Vol. II. pp. 456-487. (Ex. 2C).

		Concentration (mg/L)				% Dissolved	Total Suspended Solids (mg/L)	
		Total Dissolved P (4500PF)		Total P (4500PF)				
Sample Type		n	Avg	n	Avg			
IRW Samples	Edge-of-Field	42	4.824	42	8.1395	59%	63	268.0
	Small Tributaries - Base Flow	53	0.2873	53	0.337	85%	48	6.9
	Small Tributaries - High Flow	140	0.2932	140	0.3117	94%	177	11.3
	Rivers - Base Flow	919	0.1183	919	0.1466	81%	124	5.0
	Rivers - High Flow	148	0.0855	148	0.1186	72%	32	15.3
	USGS - Base Flow	96	0.1537	96	0.163	94%	47	7.6
	USGS - High Flow	93	0.1082	93	0.1756	62%	39	130.8
Non-IRW	Reference Samples - Base Flow (Collected Outside IRW)	33	0.0072	33	0.0138	52%	7	2.7

Pointing to these data, Olsen makes a major leap in logic. He asserts:

*“Dr. Johnson has no factual basis for his opinion concerning the controlling processes (total concentration and geochemical partitioning) in the IRW that supposedly drive the PCA and control water quality data.”*<sup>54</sup>

Olsen’s conclusion is demonstrably false, and one needs look no further than percent dissolved phosphorus data to prove it. The first point to be made in this regard is that Olsen’s analysis relies on averages (arithmetic means) which are univariate scalar measures of central tendency. One characteristic of Olsen’s IRW surface water data, which is not in dispute, is that this is a multivariate system. That was the rationale Olsen provided for using PCA in the first place.<sup>55</sup> During my deposition, within the context of the data in the above table and the associated line of questioning, I expressed my concern with the apparent assertion that this univariate analysis could shed much light on the controlling factors in Olsen’s multivariate analysis (PCA).<sup>56</sup>

Be that as it may, the data in the above table actually appear to support my opinion. Note that of seven IRW sample types on this table, the three with the lowest average percent dissolved phosphorus (Edge-of-Field: 59%; USGS-High-Flow: 62%; Rivers-High-Flow: 72%) are the same three that exhibit the highest average concentrations of total suspended solids. This is entirely

<sup>54</sup> Plaintiffs’ Motion to Exclude Johnson Testimony. Exhibit C: Declaration of Roger Olsen: p. 29 (¶ 23).

<sup>55</sup> See Olsen Expert Report (2008). P. 6-32. 1<sup>st</sup> paragraph of Section 6.11.1 Introduction. (Ex. 2A).

<sup>56</sup> Johnson Deposition. 2/25/09. Vol. II. 464:4-8. 468:22-469:4; 479:25-481:1; 485:23-486:17. (Ex. 2C).

consistent with my opinion: lower percent-dissolved P is observed in samples with higher suspended particulate matter.

However, it is still difficult to relate this data to real subject of my opinion (how geochemical partitioning effects Olsen's PCA), and not just because of the univariate/multivariate issue. It is also due to the fact that the data summarized in the above table is based on many more samples than Olsen used in his PCA. There are over 1500 phosphorus measurements summarized on this table, but only 573 samples were included in Olsen's PCA run SW3.<sup>57</sup> Simply put, it is difficult to evaluate the efficacy of an argument based on univariate analyses of a 1,524 sample data set as it applies to interpretations from a 573 sample multivariate analysis.

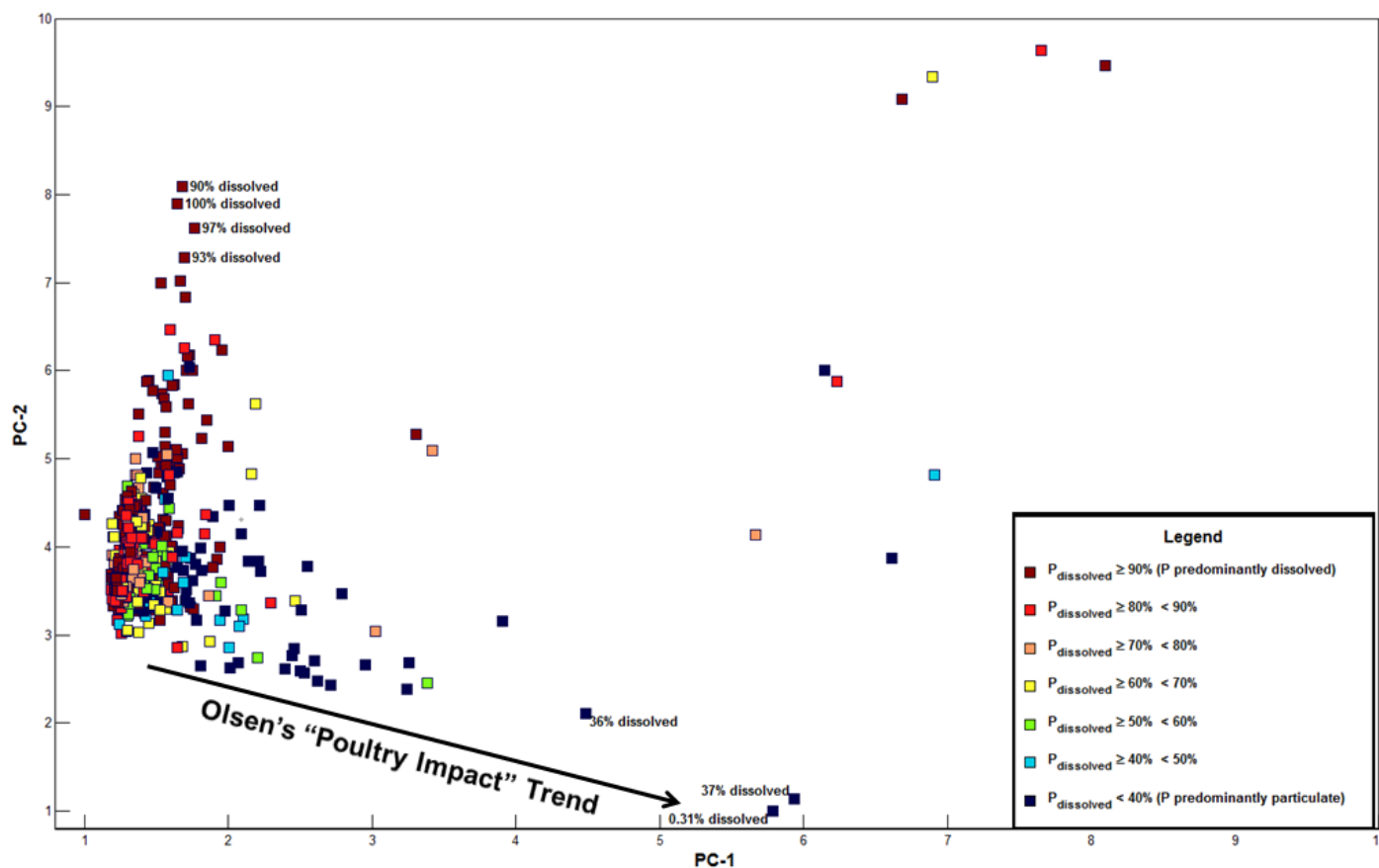
Fortunately, evaluating PCA results in context of percent dissolved phosphorus is a simple exercise. If we plot samples on Olsen's SW3 scores-plot<sup>58</sup> using symbols colored as function of percent dissolved phosphorus, and if Olsen's criticism is apt, we should see no discernable pattern in dissolved P as a function of principal component scores. But if such a scores plot exhibits a pattern of decreasing percent dissolved phosphorus as one progresses down and to the right along Olsen's trend of purported "poultry impacted" samples, then the percent dissolved P data would support my opinion.

Such a scores plot is provided in the figure below. Note that samples on the left side of Olsen's SW3 scores plot exhibit the highest dissolved P ratios (70% to >90%). As you move down and to the right along what I called the "bottom trend" in my report (and through the area that Olsen labeled as "Poultry-Waste Dominant Impact" in his report)<sup>59</sup> we see a general decrease in the percentage of dissolved phase phosphorus. If percent dissolved-P is decreasing, then percent particulate-P is increasing.

<sup>57</sup> See discussion of number of samples in Olsen's SW3 PCA data set: Johnson (2008). Section 2.2.2.2 (p. 9); Section 2.3.1 (p. 11-12);

<sup>58</sup> SW3 was the PCA run relied upon by Olsen in support of his opinions with regard to sources of P in surface water. See Olsen, 2008 ( Ex. 2A); pp. 6-53, 6-59, 6-60 and Figure 6.11-18a.

<sup>59</sup> Olsen (2008). Figure 6.11-18c. (Ex. 2A).



The above scores-plot explicitly disproves the argument in plaintiffs' motion relating to percent dissolved phosphorus. Dissolved phosphorus data does not contradict my opinion, it supports my opinion. As PC-1 scores increase along Olsen's supposed "poultry impact" trend, the percentage of dissolved phosphorus decreases, and the percentage of particle-bound phosphorus increases. To the extent that total phosphorus is explained by Olsen's PCA, it is because variability of total phosphorus is a function of its association with iron, aluminum and suspended particulate matter. I stand by my opinion.

I, Glenn W. Johnson, declare under penalty of perjury, that the forgoing is true and correct. Executed on the 5<sup>th</sup> day of June, 2009.

Glenn W. Johnson, Ph.D.

In the matter of

State of Oklahoma, ex rel., A. Drew Edmondson in his capacity as Attorney General of  
the State of Oklahoma, and Oklahoma Secretary of the Environment, C. MILES  
TOLBERT, in his capacity as the Trustee for Natural Resources for the State of  
Oklahoma, Plaintiffs

v.

Tyson Foods, Tyson Poultry, Tyson Chicken, Inc., Cobb-Vantress, Inc., Aviagen, Inc.,  
Cal-Maine Farms, Inc., Cargill, Inc., Cargill Turkey Products, LLC, Georges, Inc.,  
George's Farms, Inc., Peterson Farms, Inc., Simmons Foods, Inc., and Willowbrook  
Foods, Inc.  
Defendants.

CASE NO. 05-CV-329-GFK-SAJ

in the United States District Court  
for the Northern District of Oklahoma

Expert Report

of

Roger L. Olsen, Ph.D.  
CDM  
555 17<sup>th</sup> Street, Suite 1100  
Denver, CO 80202



poultry related contaminants are pervasive through out the IRW, the overall water quality characteristics of the surface waters in the IRW have been substantially changed when compared to surface water quality in reference locations.

- The chemical and bacterial concentrations in each environmental component are consistent with known fate and transport processes and show a gradient in concentrations from high to low across the IRW depending upon closeness to poultry land application fields. These observations document a complete pathway of the poultry waste contamination from the land applied fields to streams, groundwater, springs, sediments, and Tenkiller water and sediments.
- The chemical compositions of the poultry waste and cattle manure are different from each other and individually unique. In addition, the chemical compositions of leachates of the poultry waste and cattle manure generated using synthetic precipitation are different from each other and individually unique. The chemical and bacterial compositions of poultry waste leachates are different and unique compared to WWTP discharges in the IRW. These differences allow identification of the important sources of contamination in the basin.
- Principal component analysis (PCA) identified two major sources of contamination in the IRW: poultry waste disposal and WWTP discharges. Poultry waste is by far the dominant contamination source in the IRW when compared to other sources. Cattle waste contamination was unique from both poultry waste and WWTP effluent and was identified in some samples with documented cattle manure contamination. However, chemical contamination from cattle waste is not dominant in the basin and only represents a minor source. In the PCA, the chemical and bacterial composition of poultry waste creates a distinct chemical signature that contains both phosphorus and bacteria.
- Mass balance calculations performed using the results of the synthetic precipitation leachates show that cattle manure is a relatively small source of the chemical contamination compared to poultry waste.
- Multiple lines of evidence by other experts (Drs. Engel, Fisher, Teaf and Harwood) support the conclusions that poultry waste is a major source of phosphorus and bacteria contamination in the IRW.

The information and evaluations supporting each of these opinions is provided in the following sections. Other opinions are also included in each section.

poultry waste in the subsurface. Furthermore, two of the samples that contained quantifiable concentrations of the PLB were base flow samples from the small tributaries, which consist mainly of groundwater. In summary, the PLB has been detected in all environmental components of the IRW.

## **6.11 Chemical and Bacterial Signatures using PCA Techniques**

### **6.11.1 Introduction**

Principal component analyses (PCA) is a multivariate statistical technique. Multivariate means that multiple response variables or parameters (contaminants) were measured and are available for evaluation. Multivariate analyses make use of correlations between variables to help explain important relationships and reduce the number of variables needed to describe relationships of concern. In an environmental context, PCA is used on sites with a large number of contaminants and allows us to determine the differences and relationships among all of the contaminants. These relationships are used to identify sources of contamination.

PCA is probably the oldest and best known of the techniques of multivariate analysis (Jolliffe, 2002). PCA was first introduced by Pearson (1901) and developed independently by Hotelling (1933). PCA is a well established statistical technique in environmental and other scientific disciplines. In particular, PCA has been used to evaluate sources of contamination in the environment. A list of publications concerning use of PCA in evaluating environmental conditions is provided in **Table 6.11-1**. **Table 6.11-2** provides excerpts from some of the publications with respect to source evaluations and conclusions. These documents show that PCA is a reliable and accepted scientific technique and can be used to identify sources of contamination in watersheds such as the IRW.

**Table 6.11-3** provides a comparison of important attributes of four selected publication studies used to identify sources of contamination in watersheds. The same attributes for the IRW evaluation are also provided in the table. As shown in **Table 6.11-3**, the IRW study and PCA evaluation were very similar to the published studies in terms of key study attributes for PCA such as watershed size, number of samples, number of parameters used in the PCA, number of data points, number of sources identified, and percent variance explained by meaningful principal components. The IRW discussed in this report has a significant more number of sampling stations and the major principal component explains more variance than the other studies summarized in **Table 6.11-3**.

### **6.11.2 Steps of PCA**

The steps used to perform the IRW PCA were as follows:

- Step 1: Formulate a conceptual site model
- Step 2: Define objectives and state hypothesis

PC 1, and therefore if these or a subset of these variables can be shown to be related to a particular waste source, then samples with high PC 1 scores can be related to, or have signatures consistent with, that source. Similarly, PC 2 exhibits relatively high loadings for a different set of variables: chloride, sodium, and sulfate, which may indicate a relationship to another source. The threshold loading (0.6) in this example is arbitrary and has been selected solely for illustrative purposes: such thresholds are commonly adjusted based on additional information available to the investigator. **Figure 6.11-11** provides the bar charts for Run SW 3 for both PC1 and PC2 with the coefficients shown instead of the loadings. **Figures 6.11-12** and **6.11-13** provide the loadings and coefficients for PC1 and PC2 for SW17. **Figures 6.11-14a** and **6.11-15a** provide the loadings and coefficients for SD1. **Figures 6.11-14b** and **6.11-15b** provide the loadings and coefficients for SD1 using the varimax rotation. **Figures 6.11-16** and **6.11-17** provide the loadings and coefficients for PC1 and PC2 for SD6.

### Step 11: Calculate Principal Component Scores

Principal component (PC) scores are calculated for each identified significant PC for each individual sample. Identification of significant PCs was discussed in Step 10. To calculate a PC score for each individual sample, the PC coefficient is multiplied by the standardized parameter concentration. This is performed for all parameters (variables) in a particular PCA run. The product values for all 25 parameters are summed to yield one PC score for each sample for each PC. Hence, a particular sample will have both a PC 1 score and a PC 2 score. If one of the variables selected in a particular PCA run is missing a value (due to it not being measured), the product (coefficient times the standardized concentration) for that parameter is essentially not used in the summation: this is the same as multiplying the coefficient by the standardized mean concentration which is zero. Sensitivity runs were performed using datasets with no missing value (Step 14)

Once the PC scores have been calculated for each significant PC, they are examined graphically via PC-by-PC scatter plots. Since EDAnalyzer extracts (for examination) the top five PCs, the number of scatter plots produced for possible examination will be:  $(5)(4)/2 = 10$ , i.e., PC 1 vs. PC 2, PC 1 vs. PC 3, PC 1 vs. PC 4, PC 1 vs. PC 5, PC 2 vs. PC 3, PC 2 vs. PC 4, PC 2 vs. PC 5, PC 3 vs. PC 4, PC 3 vs. PC 5, and PC 4 vs. PC 5. Furthermore, since the PCA is conducted using five different possible rotation variations: no rotation, varimax, equimax, quartimax, and oblimin, a total of:  $(10)(5) = 50$  PC scatter plots were actually produced.

PC1 vs PC2 plots are provided for the following PCA runs:

- SW3 (Surface Water)
  - Figure 6.11-18a
  - Figure 6.11-18b (expanded view)
  - Figure 6.11-18c (shows two major groups - WWTP impacted waters and poultry waste impacted waters)
  - Figure 6.11-18d and e (sample types identified)

- Of the highest 65 PC2 scores, 10 are from edge of field samples. However the chemical/bacterial compositions of these 10 samples are distinctly different than effluent from WWTPs and are discussed in detail in Section 6.8. These 10 samples also have very high PC1 while the WWTP impacted samples do not have high PC1 scores. These 10 samples are not WWTP effluent impacted but are thought to be fresh leachates collected during very high runoff conditions. These samples could potentially contain both cattle manure and poultry waste contamination.

#### ***Summary Observations***

Because of the spatial analysis and comparisons to waste compositions, PC1 has been identified as related to poultry contamination (i.e., a poultry waste signature) and PC2 has been identified as related to WWTP discharge (i.e., a WWTP signature). In addition, high PC1 scores are observed along the major flow pathways and are higher near sources of poultry waste land application and decrease with distance from the source areas. The evaluation of these observations is performed in conjunction with the next two Steps of the PCA evaluation: step 13 (Use of PC Scores to Determine Sample and Locations Impacted by Major Sources of Contamination) and step 14 (Investigative and Sensitivity Runs).

#### **Step 13: Use the PC Scores to Determine the Samples and Locations in the IRW that are Impacted by Major Sources of Contamination**

As previously discussed in Step 12, a spatial evaluation was performed to evaluate the individual sample PC scores in relation to distance from sources, sample group, sample conditions and reference locations. In this step the individual PC scores were evaluated to determine the magnitude of impact or contamination from sources across the basin. If contamination is pervasive and dominant across the IRW in all environment components, a pattern or signature groups of each major source of contamination should be observed when evaluating PC scores relative to each other.

**Figures 6.11-18a and 6.11-18b** provides a plot of the PC1 (x-axis) vs the PC2 (y-axis) scores for run SW3. **Figure 6.11-f** shows all 573 scores and **Figure 6.11-18b** shows only the scores for the samples inside the box shown in **Figure 6.11-18a** ("Area of Expanded View"). **Figure 6.11-18c** shows all points in the expanded view area (560 out of the 573 samples are shown). The figure also shows lines around the two major groups of samples identified from PC1 and PC2 evaluations. The group with high PC1 scores is labeled "poultry dominant impact" and contains the samples whose chemical and bacterial composition is dominated by poultry contamination. The group with high PC2 scores is labeled "WWTP dominant impact". These are the samples in which the WWTP impact or influence on the sample is greater than the poultry impact. There are 57 samples in this group (10 % of total). It is important to note that except for some of the reference samples, most of the samples (even those "dominated" by WWTP) show some poultry contamination.

The two groups were selected by examining the locations and chemistry/bacterial composition of the individual samples. For the "WWTP dominant impact" group, the PC2 scores were selected to be above a value of 4.7. As shown in **Table 6.11-11**,

samples below about a score of 4.8 are typically not in locations downgradient of WWTP discharges so cannot be impacted by WWTPs. For the "poultry waste dominant impact" group, a PC1 score of greater than 1.3 was selected. This is a conservatively high value and could have been set lower to include more samples. The value was selected by examining the locations and scores of samples, particularly the scores of reference samples and samples in low poultry density areas. In summary, the samples with PC1 scores below approximately 1.3 include all samples from reference locations (six total), 9 out of 10 samples from HFS30 (small watershed location with low poultry house density) and 10 out of 11 samples from HFS28A (small watershed location with low poultry house density). The one sample from HFS30 and the one sample from HFS28A with higher PC1 scores were collected during extreme flow events. Overall, 441 of the 573 samples (77%) had PC1 scores higher 1.3 and show some poultry contamination.

Figure 6.11-23 shows the average PC1 scores by location (based on PCA run SW3). The average PC1 score was determined if multiple samples were collected and contained in the PCA analyses by calculating the mean score of those samples. In Figure 6.11-23, there are 175 different locations. Of these, 137 have a PC1 average scores greater than 1.3. Therefore, approximately 78 percent of the locations sampled in the IRW show some poultry contamination. Locations with PC2 scores higher than 1.3 are shown in red; those with scores less than 1.3 are shown in green.

The following table gives a breakdown of the number of samples with poultry contamination by the various sample types (based on run SW3):

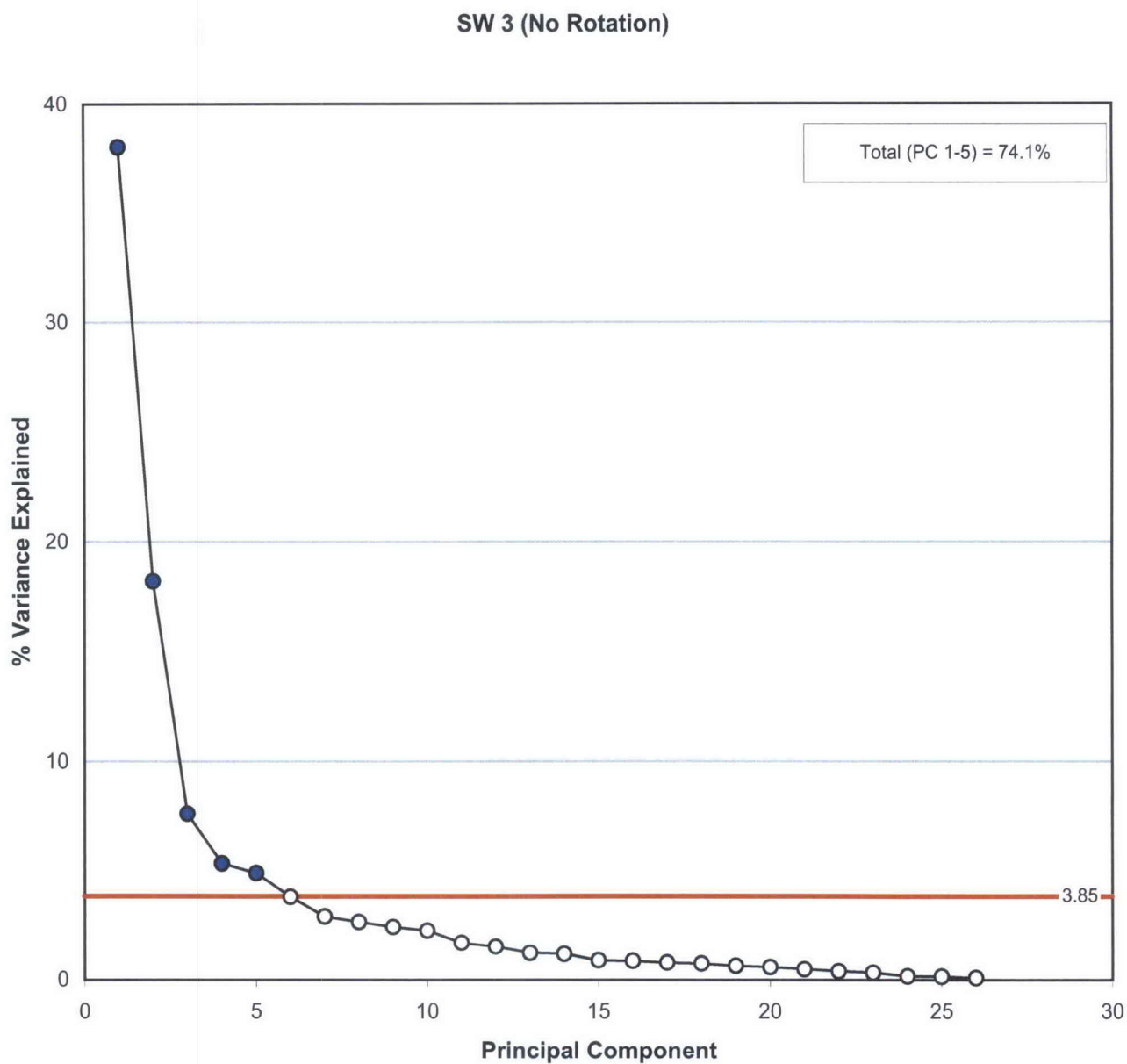
Sample Type	Sample Counts	Percent > 1.3
EOF	65/65	100
Lake Tenkiller	29/29	100
Stream - base flow	56/90	62
Stream -high flow	13/20	65
Small Trib-base flow	32/48	67
Small Trib-high flow	158/177	89
USGS - base flow	32/48	67
USGS - high flow	60/81	74

Note: the three WWTP discharges samples are not included because they are actual source samples; reference samples are included in the "streams" group.

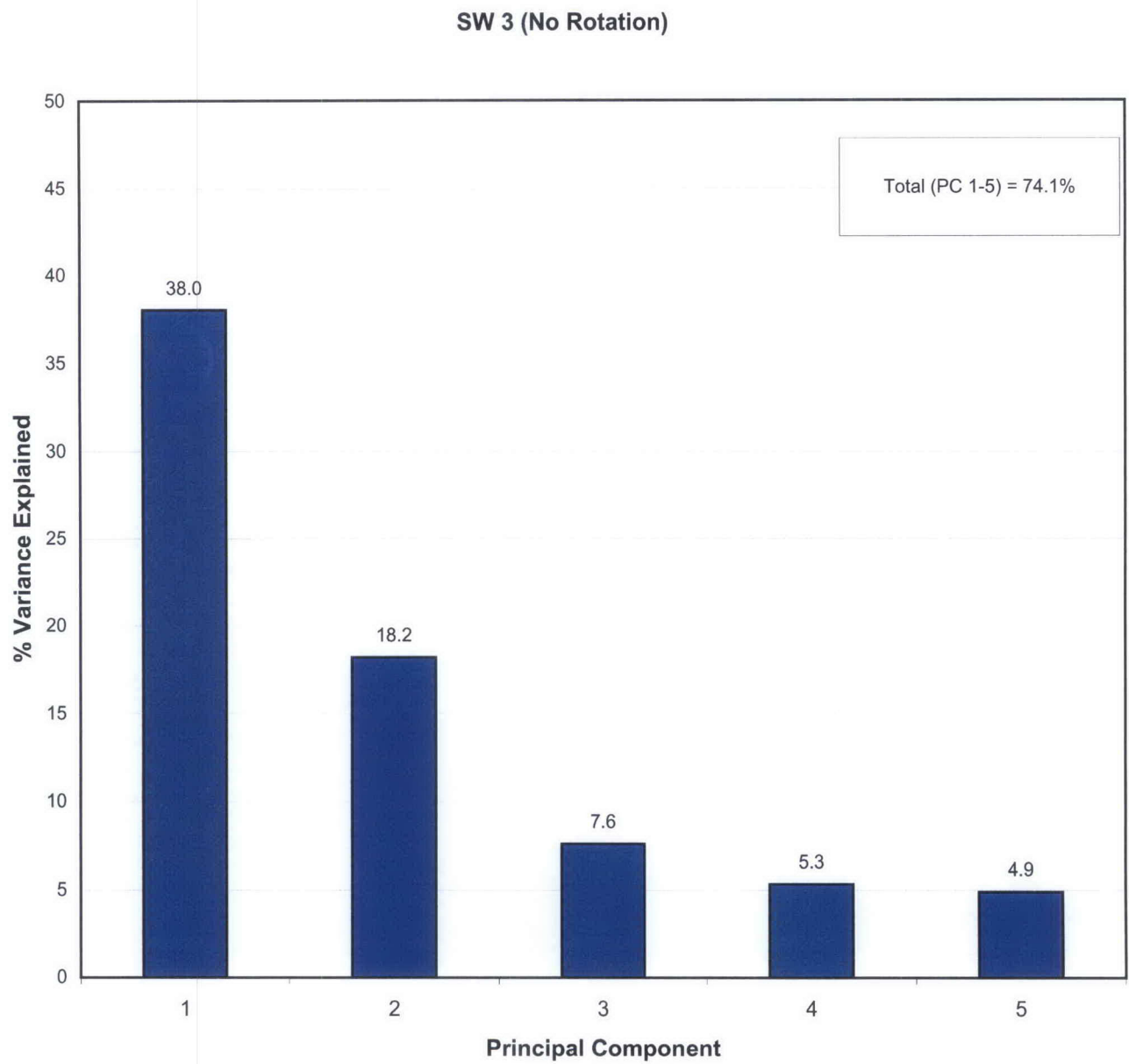
#### *Evaluation of Groundwater and Spring Samples*

Figures 6.11-19a and 6.11-19b show the PC1 score vs PC2 score plot for PCA run SW17. This run is the same as SW3 except groundwater samples (geoprobe and existing wells) and springs samples are included in the PCA. This results in 699 total samples in the PCA. The results of this run are provided graphically and include:

- **Figures 6.11-3 and 6.11-4:** Scree Plots and Variance Analysis
- **Figures 6.11-12 and 6.11-13:** PC Parameters, Loadings and Coefficients

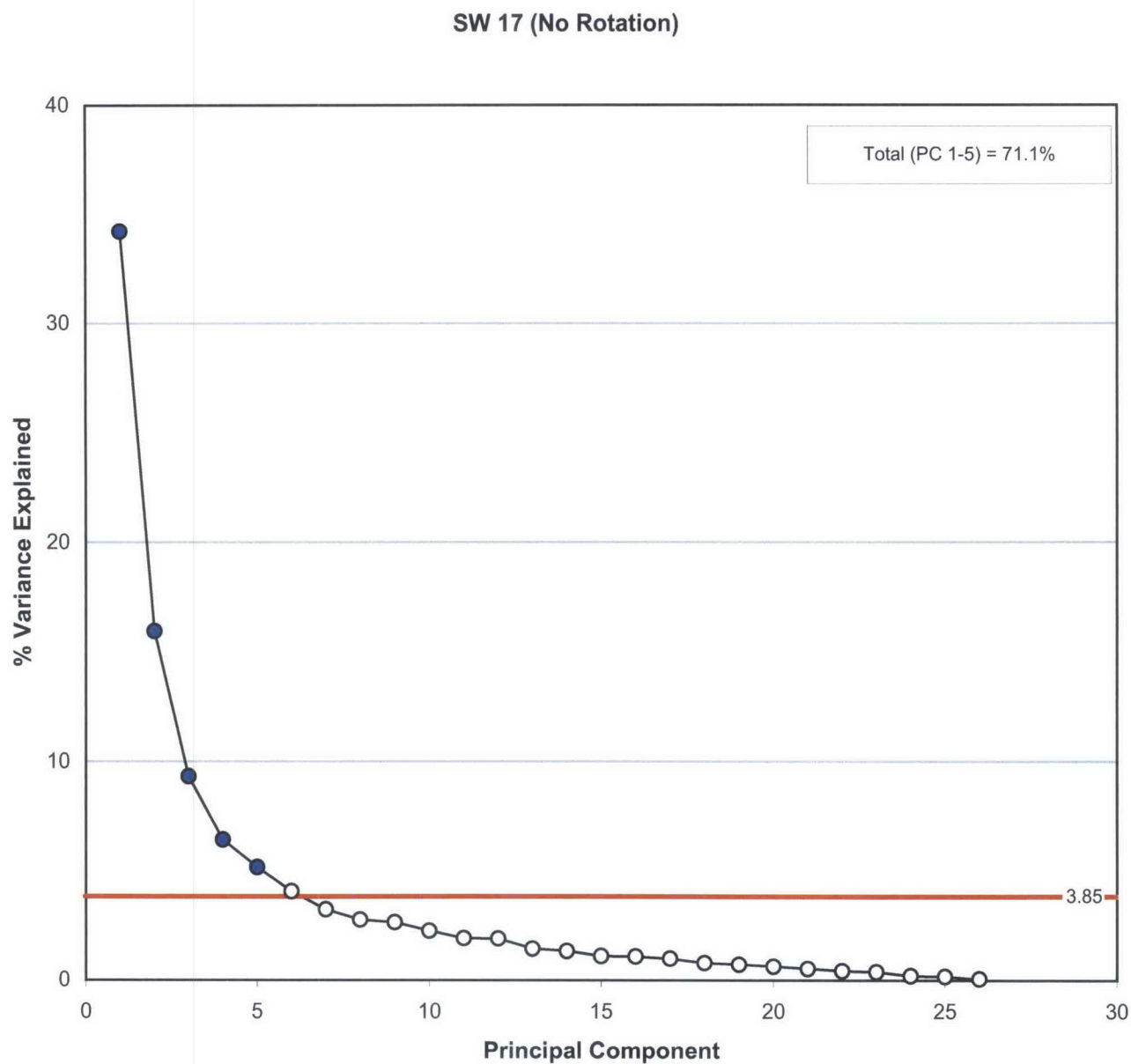


**Figure 6.11-1**  
**Scree Plot: Surface Water (SW3)**

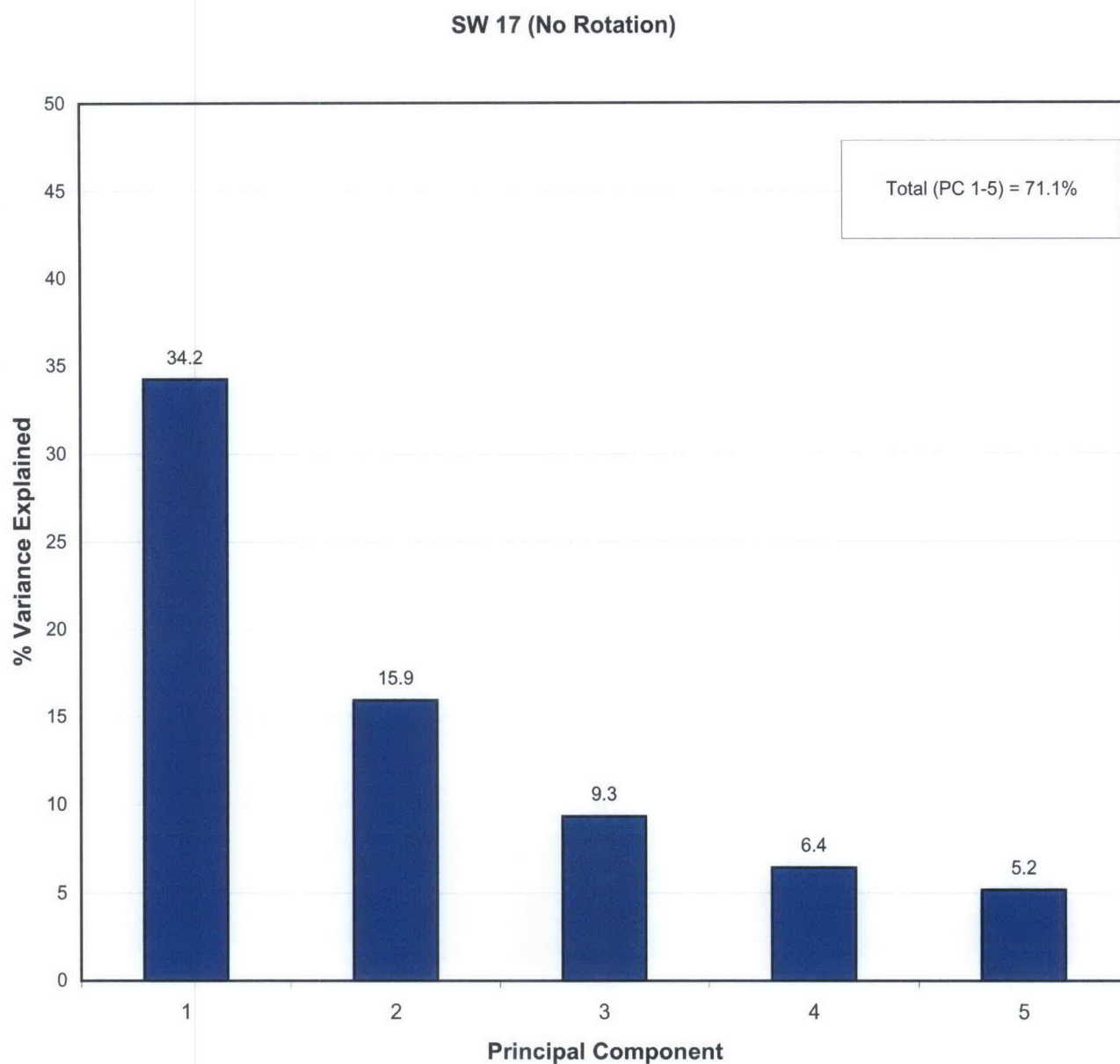


**Figure 6.11-2**  
**Bar Chart with % Variance (SW3)**

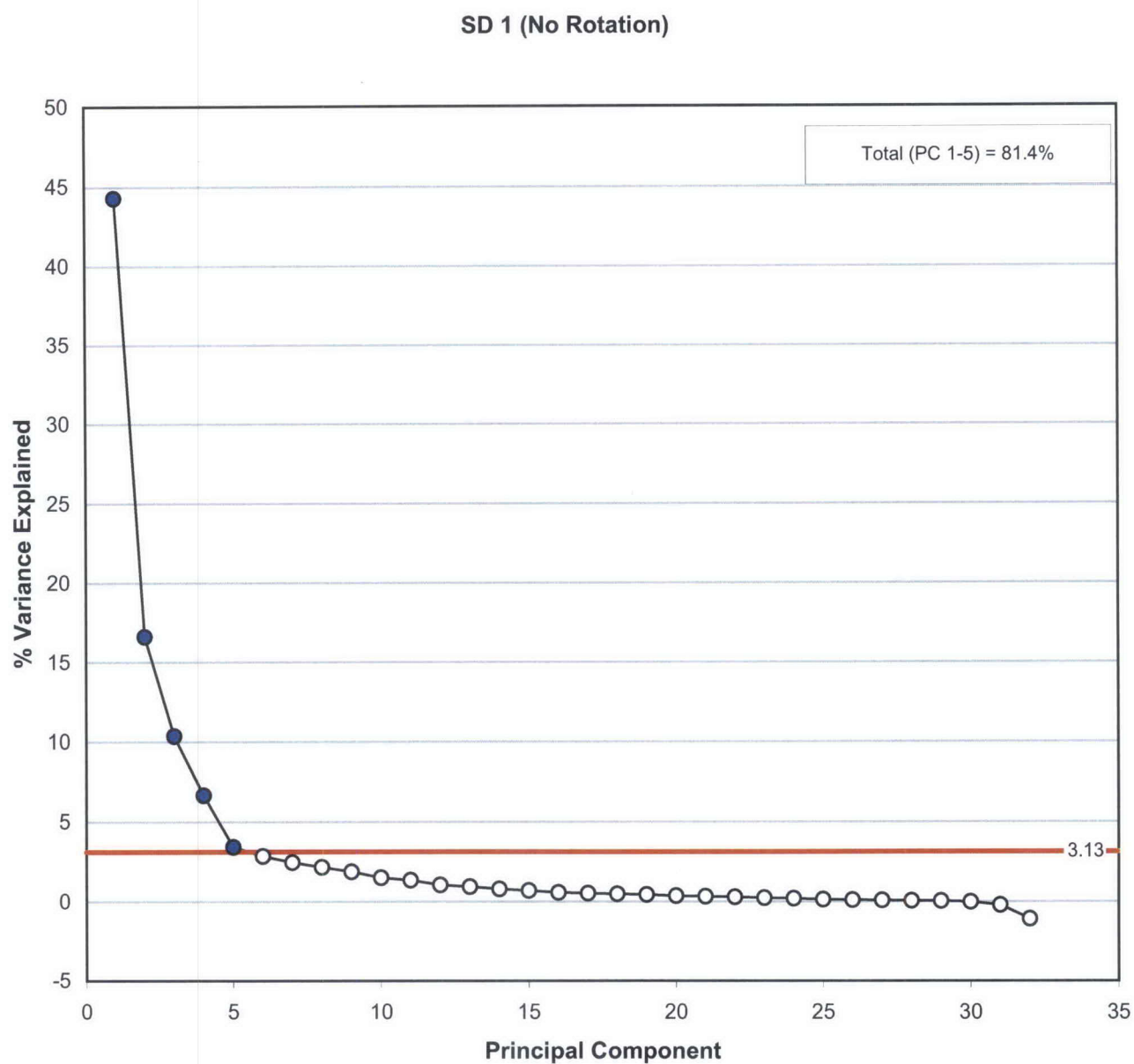




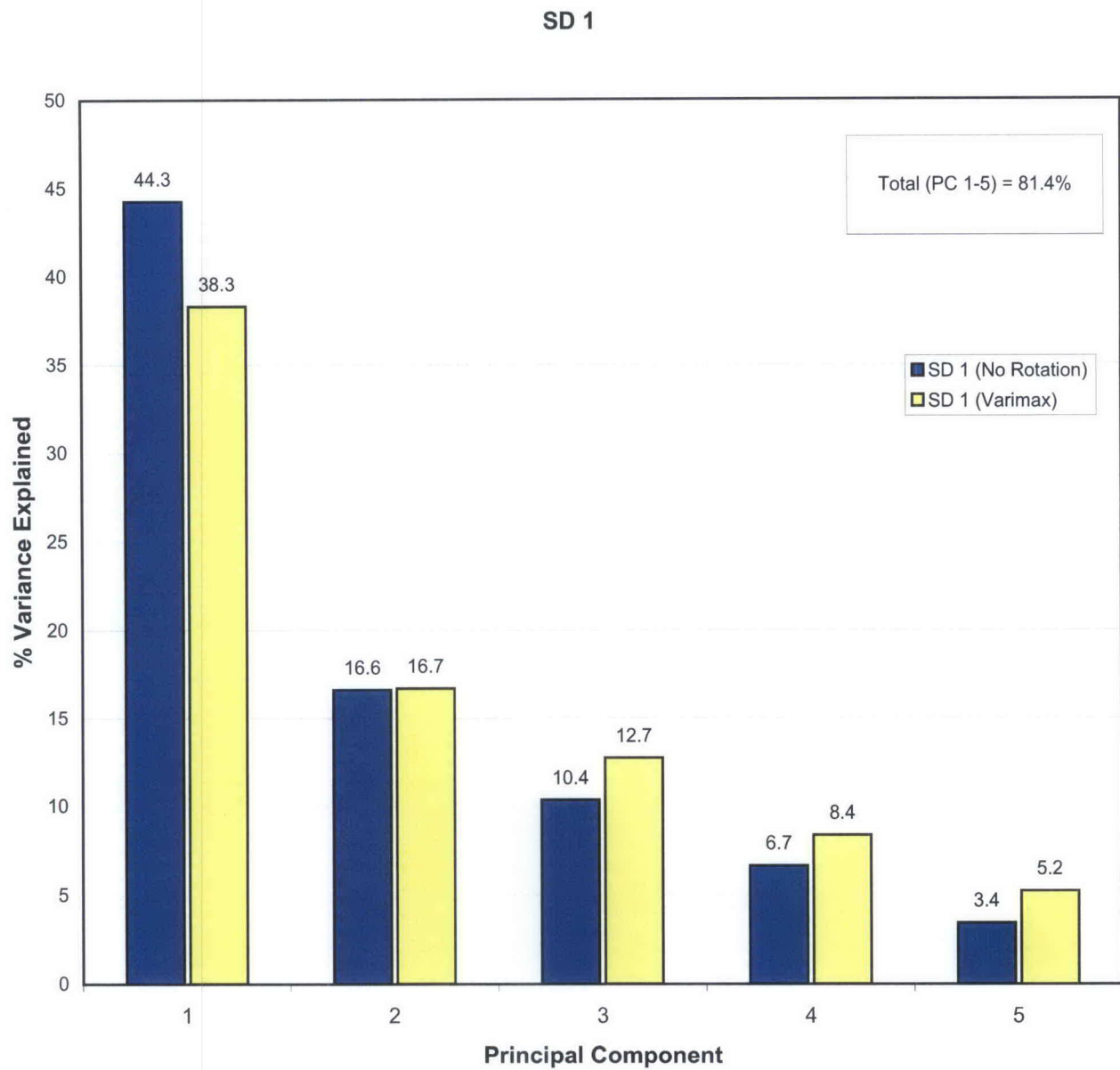
**Figure 6.11-3**  
**Scree Plot: Surface Water and Groundwater (SW17)**



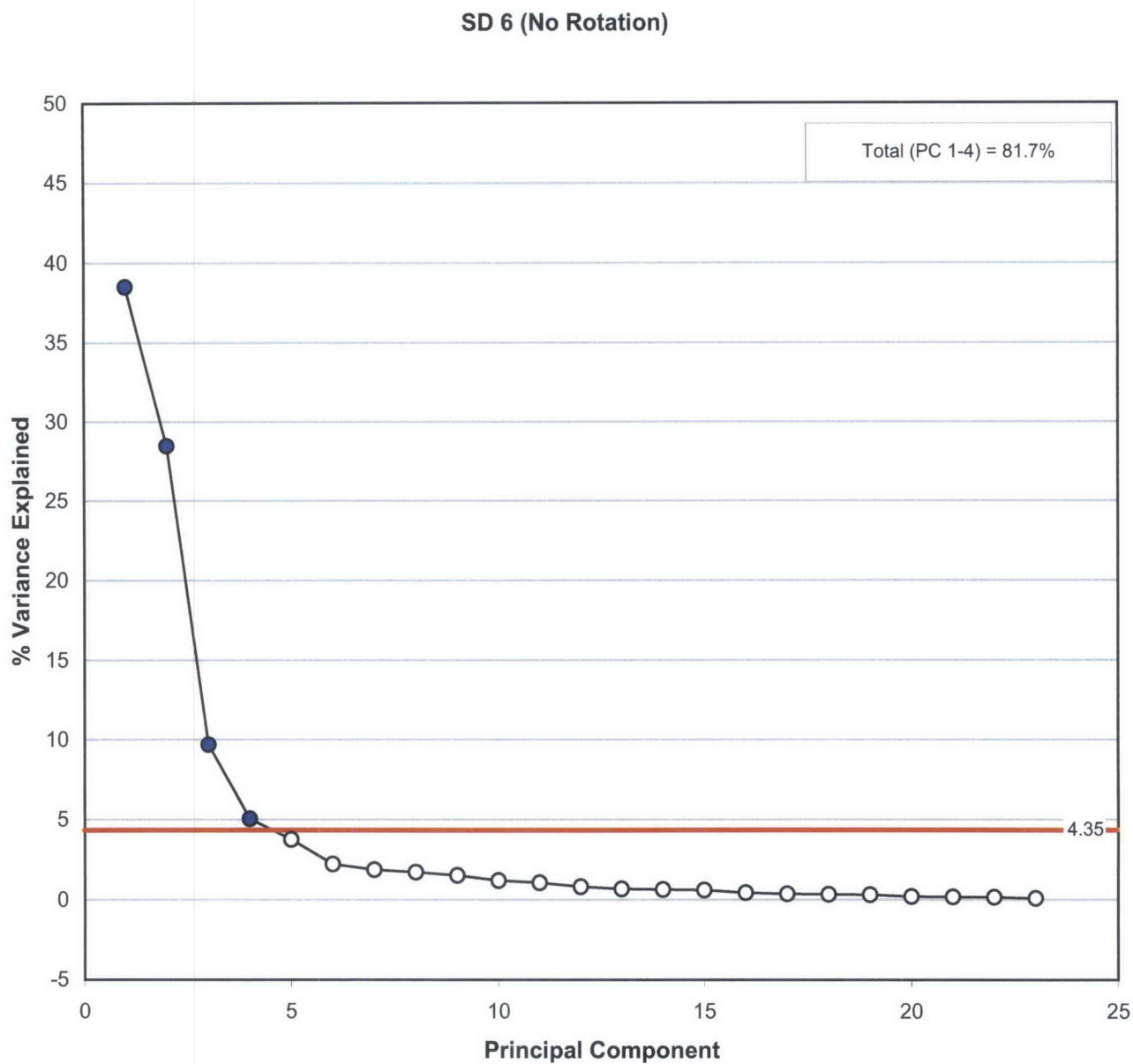
**Figure 6.11-4**  
**Bar Chart with % Variance (SW17)**



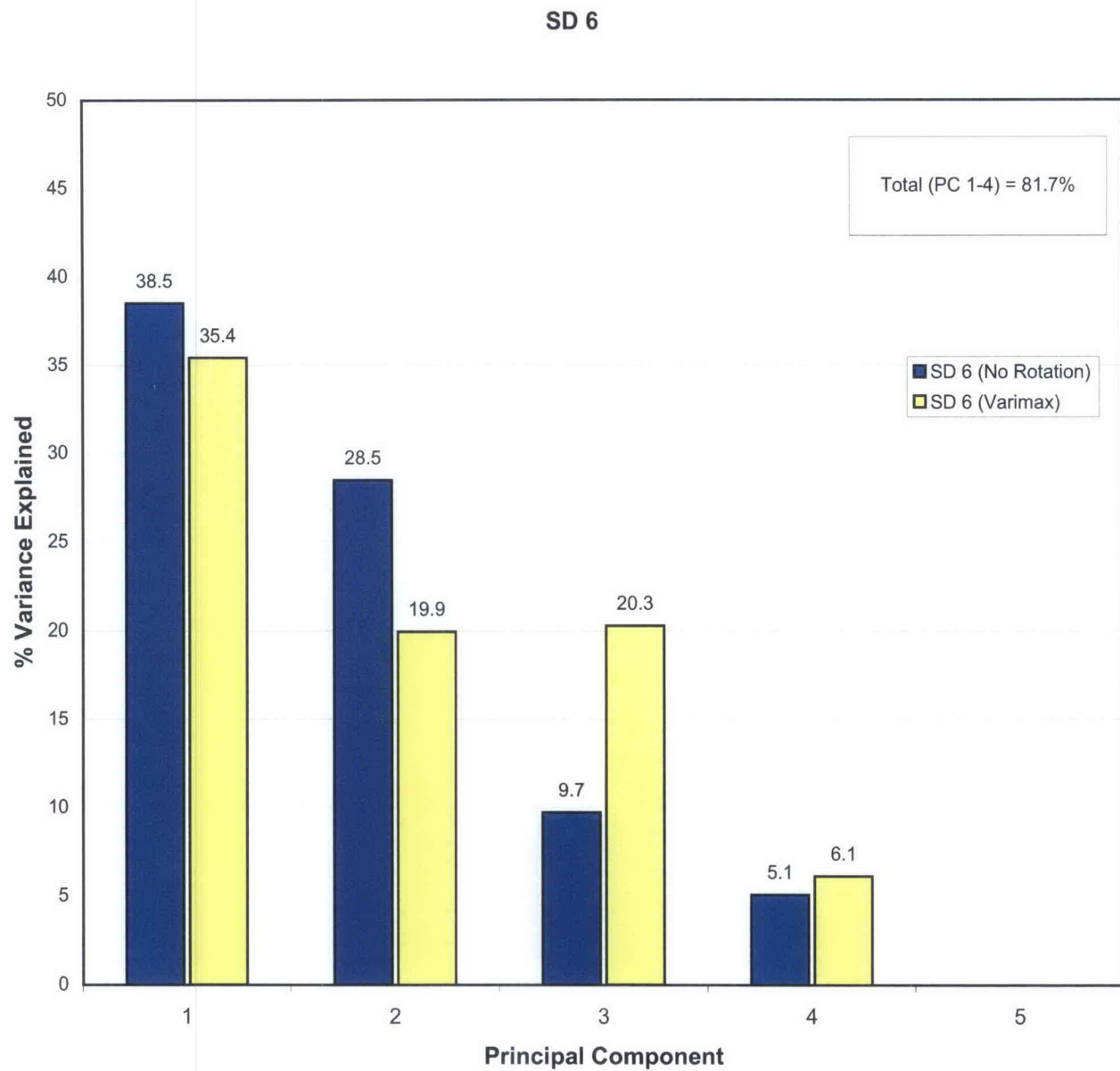
**Figure 6.11-5**  
**Scree Plot: Solids (SD1)**



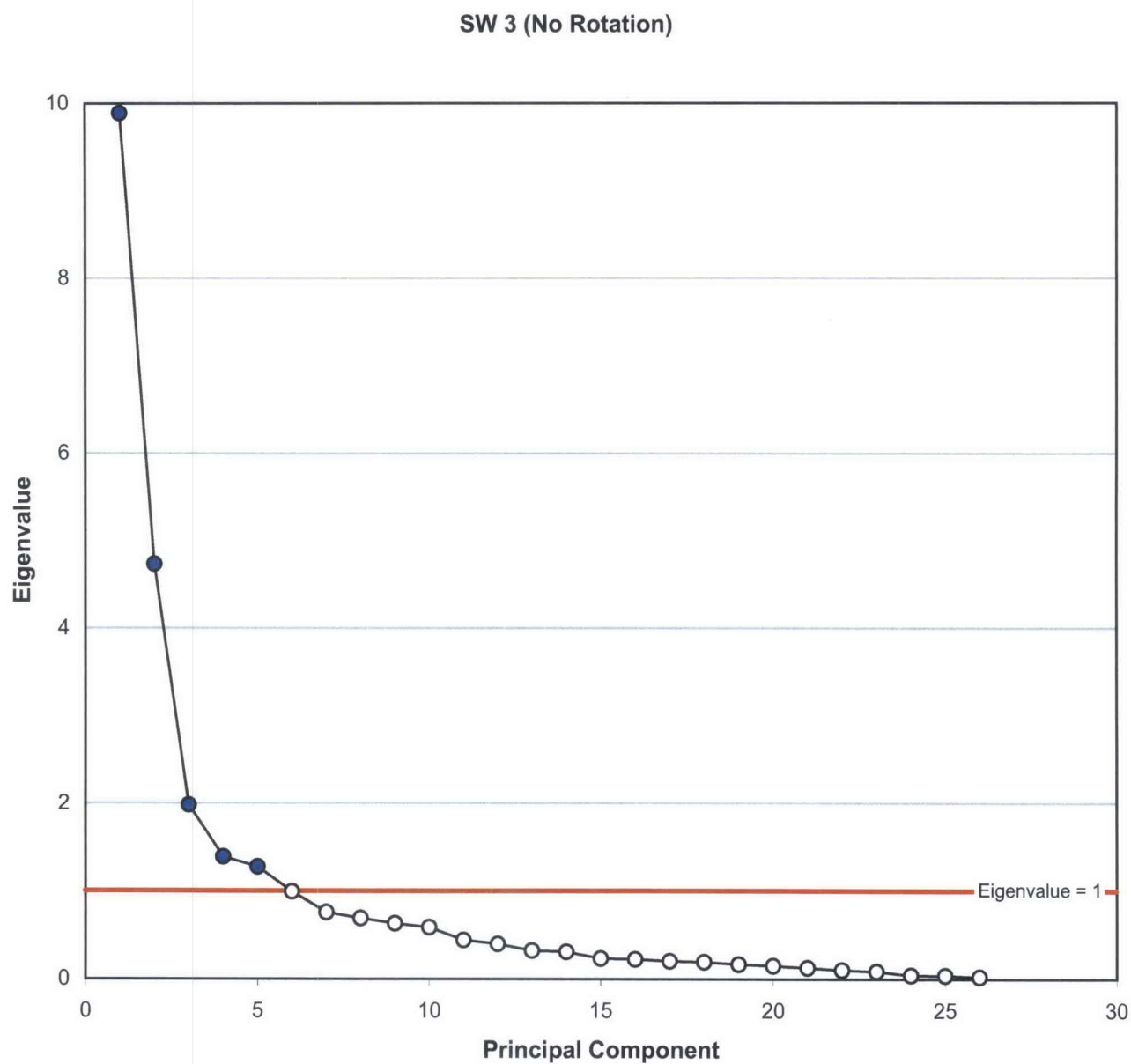
**Figure 6.11-6**  
**Bar Chart with % Variance (SD1)**



**Figure 6.11-7**  
**Scree Plot: Solids with Core Samples (SD6)**



**Figure 6.11-8**  
**Bar Chart with % Variance (SD6)**



**Figure 6.11-9**  
**Eigenvalue: Surface Water (SW3)**



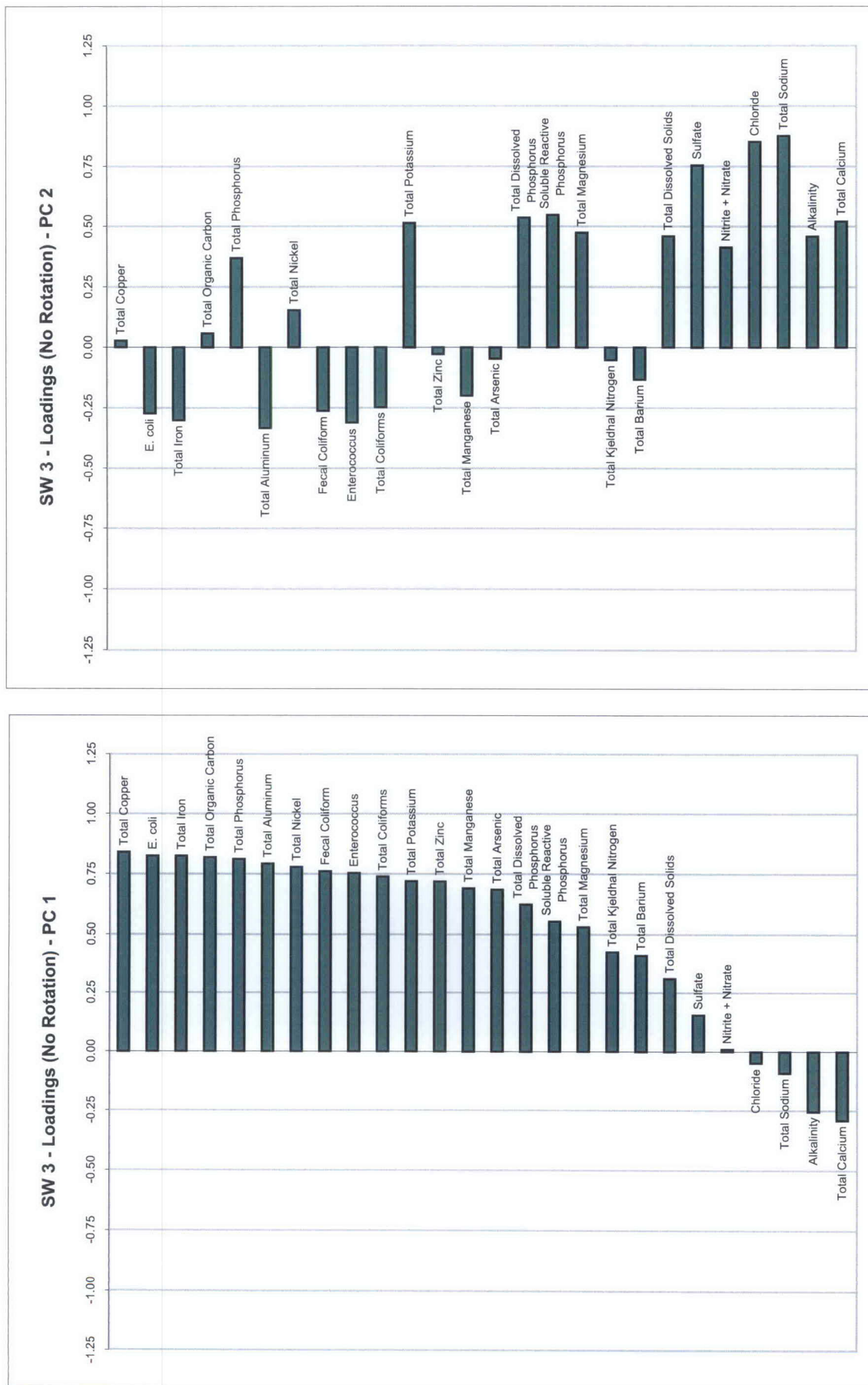


Figure 6.11-10  
Loadings (SW3)

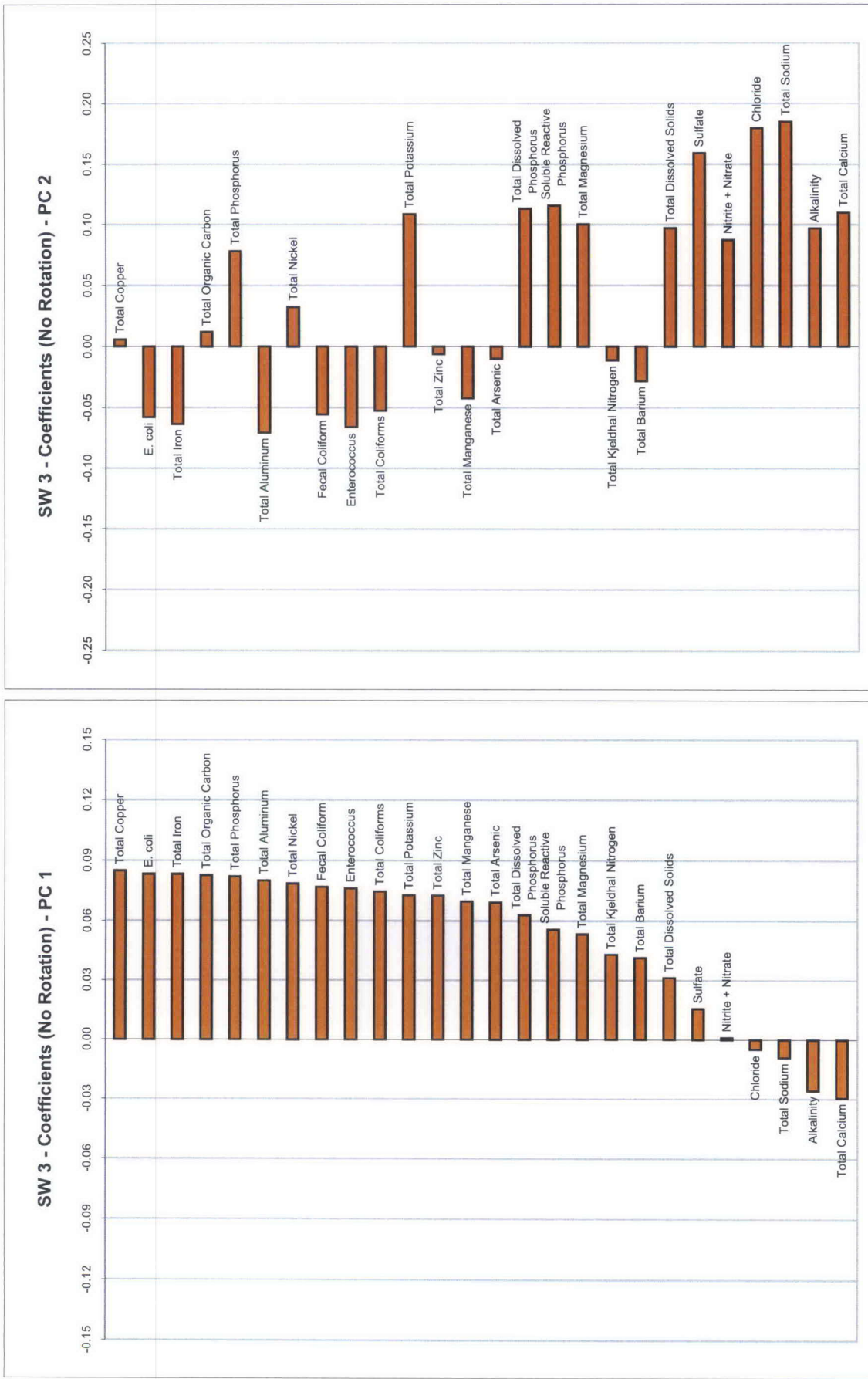


Figure 6.11-11  
Coefficients (SW3)

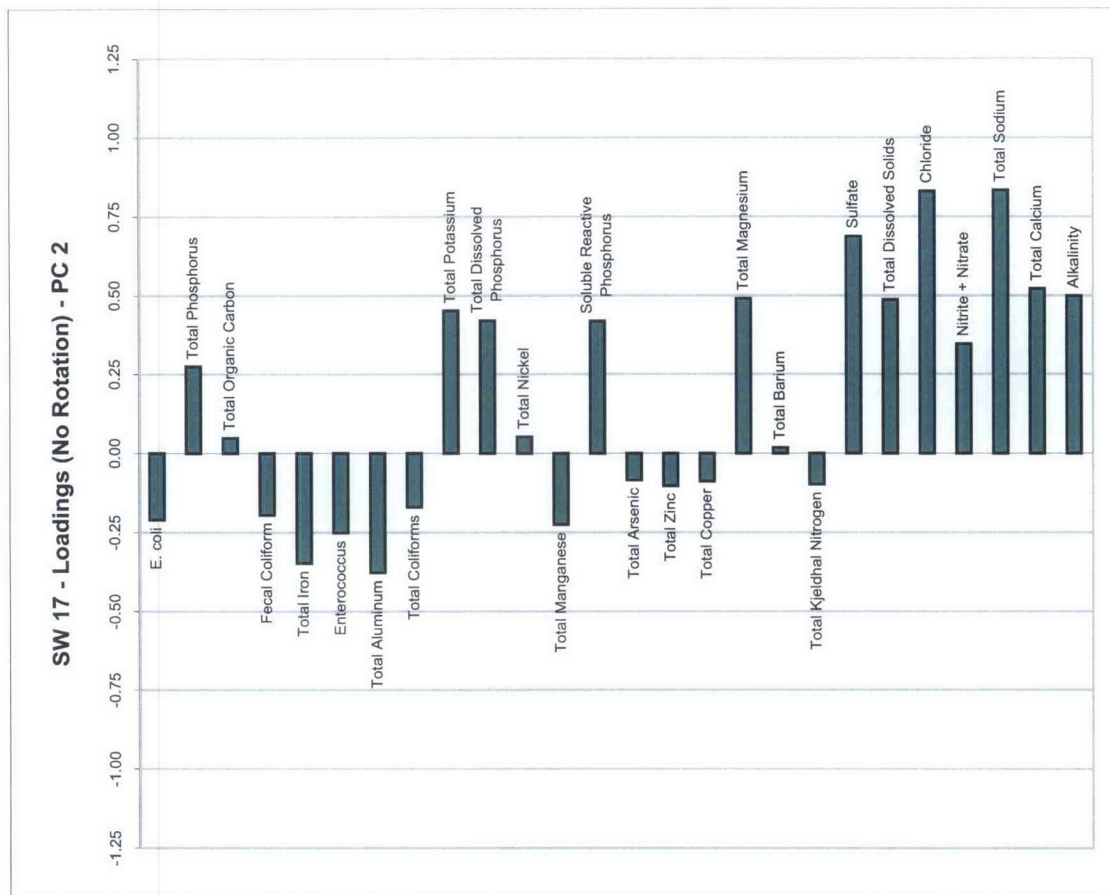
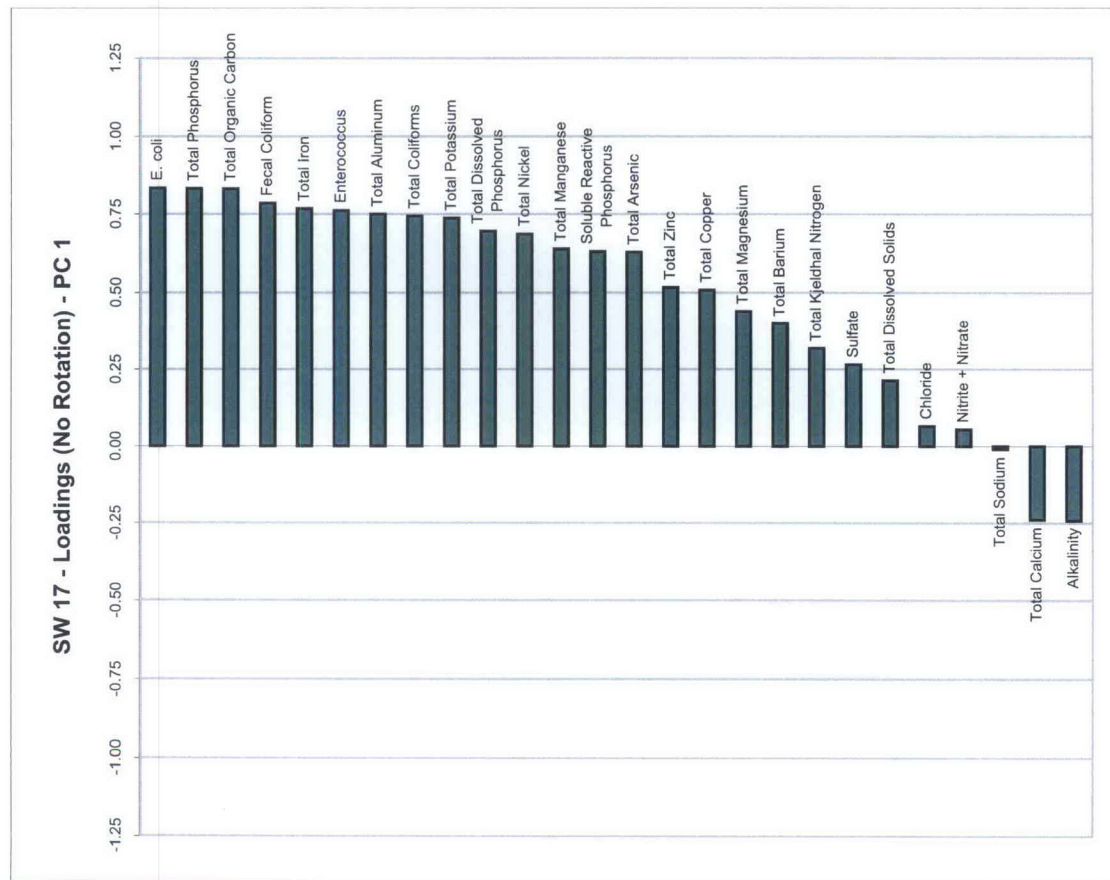


Figure 6.11-12  
Loadings (SW17)

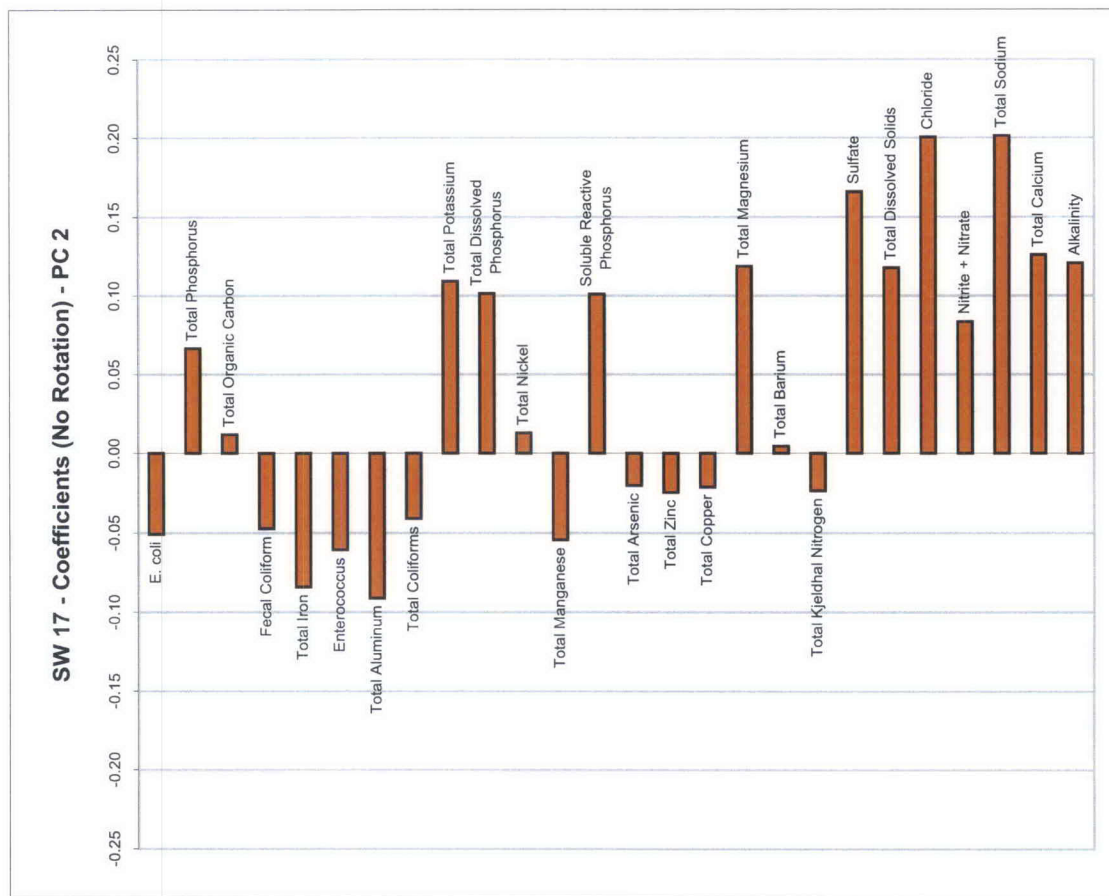
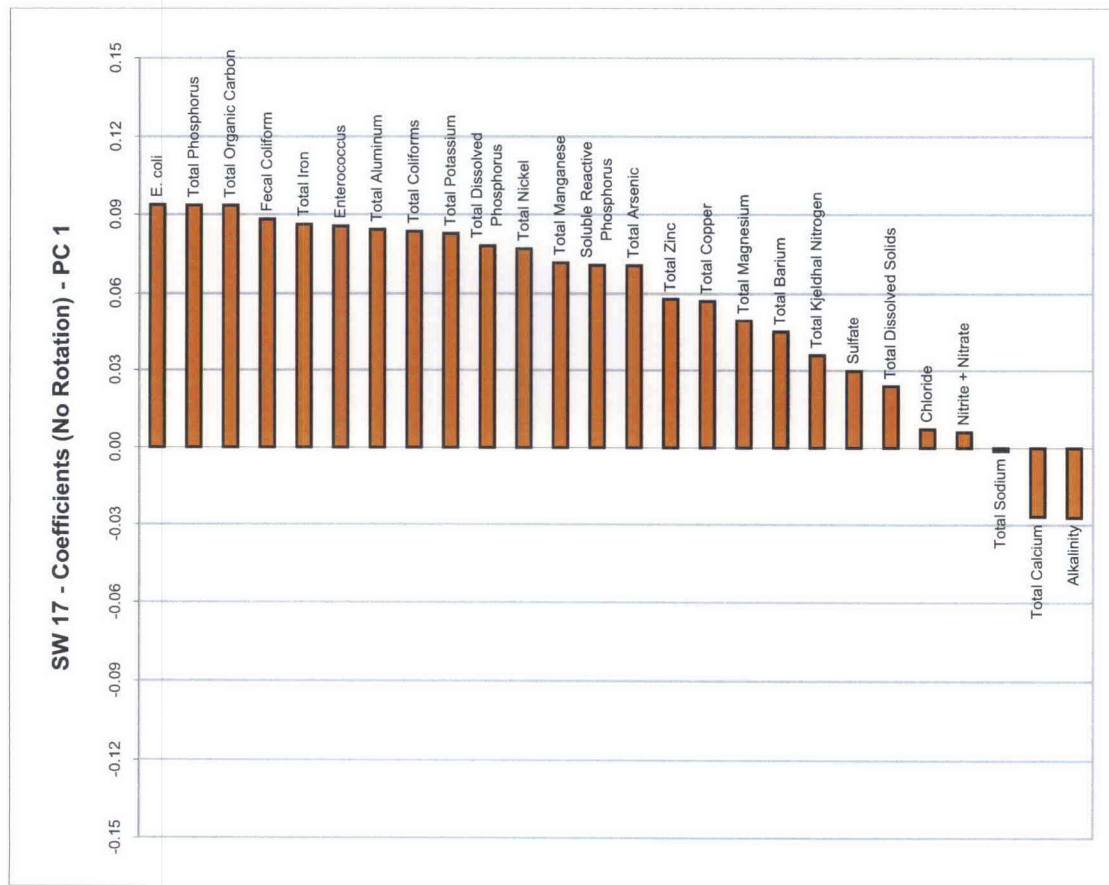


Figure 6.11-13  
Coefficients (SW17)



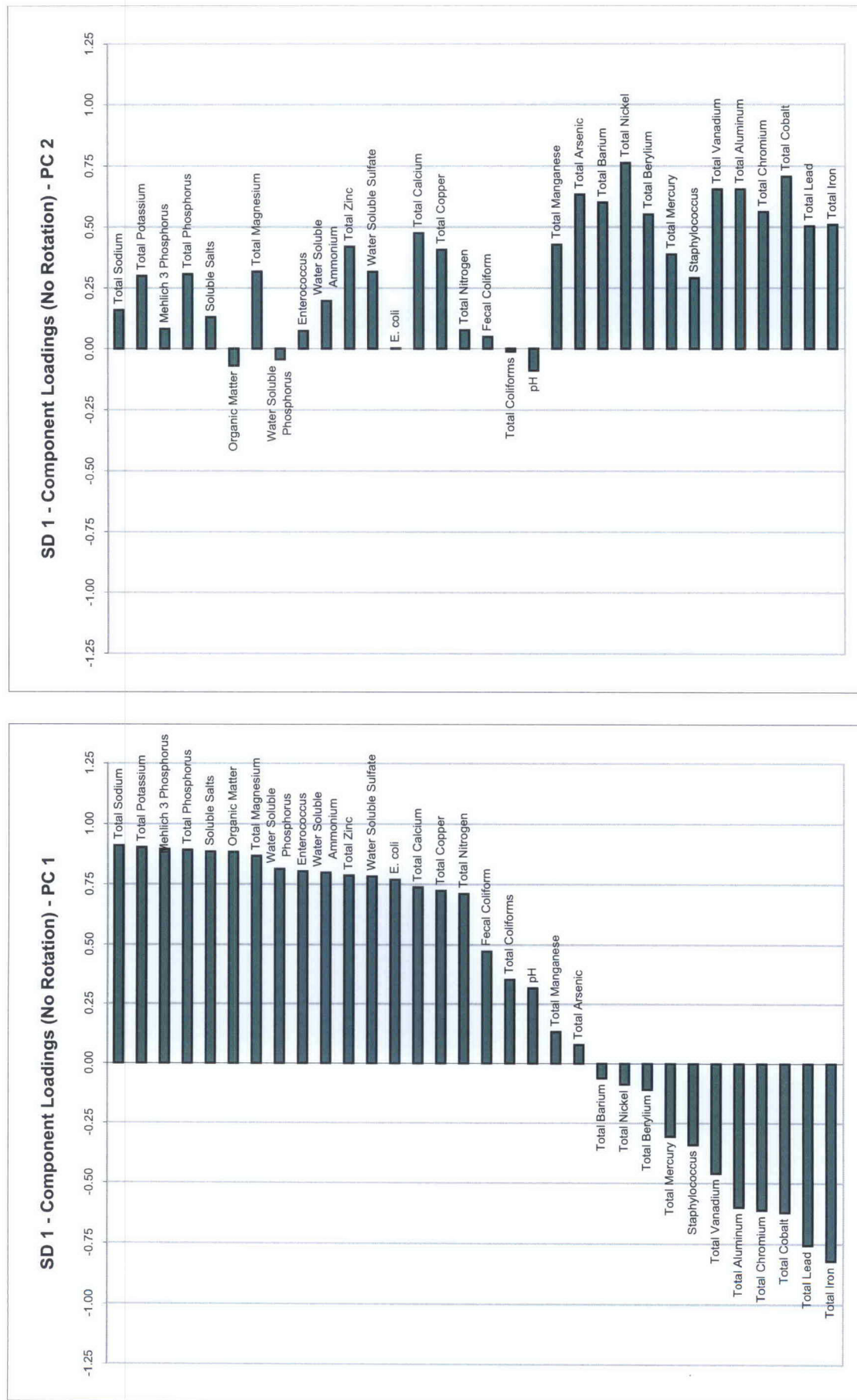


Figure 6.11-14a  
Loadings (SD1)

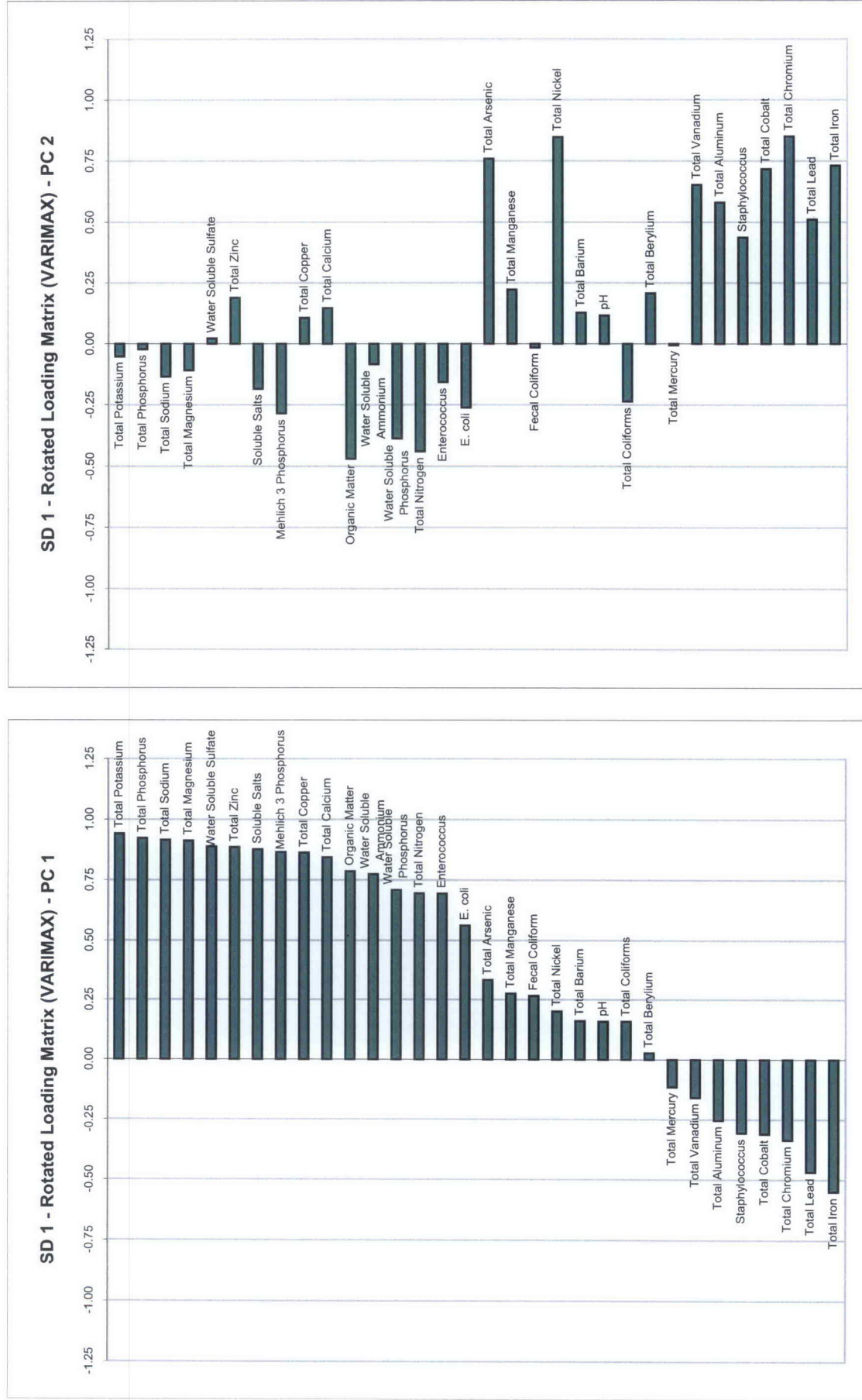


Figure 6.11-14b  
Loadings (SD1 Varimax)